Looking at the Landscape

By the same author

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LOOKING at the LANDSCAPE

by

Walter Shepherd

WITH 60 DRAWINGS BY
THE AUTHOR

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Three Ways of Looking at a Landscape

When you climb to the top of a hill to look at the view you expect to receive some kind of pleasure for your trouble. There is, of course, the physical pleasure of the climb and the feeling of being on top of the world, but the view itself—the landscape—may well be worth seeing for its own sake.

Now, there are three different ways of looking at a landscape—four, if you like picking out places you know with a telescope (but you can do that without a book to help you!). The first way is simply to admire the view. You like the shapes of the hills and the pattern made by the fields, and perhaps you notice the strange effects of a mist or the way the cloud-shadows chase each other across the country. In short, you look at it as you would look at a picture, only it is a 3-D picture with things moving about in it.

This is the way most people are looking at a landscape when they exclaim, 'What a lovely view!' It is the way artists and poets look at it, too, but they go farther and seek ways of expressing the landscape's character and the feelings it arouses in them. A book about this sort of enjoyment of the scenery would have to be very vague and philosophical unless it talked about particular places, and that would hardly be fair to readers who had never seen them.

So I have not said much about this way of looking, though there had to be a little because it is a very important way, and to leave it right out would be like giving you a dinner with no flavour in it! What I have done—without getting tied down to particular places—is to quote what a few of the poets have said about some of the subjects. This will give you an idea how you may, if you choose, see similar subjects when you come across them.

The second way of looking at a landscape is to see it as a stretch of country in which people, animals and plants all live. You notice the villages, the plantations of trees, the different kinds of fields—green grass, yellow mustard, blue cabbages, golden corn, red poppies—and how the mill stands by the river and the church on the hill. This time you are not really interested in the patterns and colours but in what they stand for, so here again everything depends on the particular place you are looking at—and even on the time of the year.

This way is important, too, but to cover all the different kinds of country we should need a much larger book than this one. Fortunately the types of plants and buildings in a landscape sometimes give a lot of general information about it, just as national costumes can tell you something about the people who wear them, though you may not know them personally. So in suitable places I have pointed out how the nature of a landscape can be told from what stands on it.

The third way of looking at a landscape is what we are going to talk about most. This is to observe the shapes of the hills and valleys, the courses of the rivers, the kinds of sea-shore and such-like details, and then

try to account for them. The advantage of this way is that once you understand what to look for it doesn't matter where in the world you happen to be. The same kinds of results are produced by the same kinds of causes wherever you are, so we don't have to bother about particular places at all.

This way of looking, like the second one, means that we have to think a lot about what we see, but it is different in one important way. Much more of our thinking has to be done with our imaginations, because now our eyes provide us with mere *clues* to what is going on. We have to become detectives, and because the clues we need are good, solid, down-to-earth things like stains, odd rocks, tell-tale pebbles and holes in the ground, we have to do a good deal of walking about to find them.

These three ways of looking at a landscape are really so different that we must be rather careful not to get them confused. Poetry and detective-work, particularly, do not mix, and if, for example, I am looking for clues to account for a cave I have found, it will not help me much to think of it as 'yawning'! Now, yawning may describe its *appearance* very well, but it is part of a detective's work to get behind appearances—to penetrate disguises.

I may discover that my cave has been made by the sea and fancy that this must be the *real* truth about it. But if I think it is the only sort of truth I am making a mistake. Part of the cave *is* its appearance, and a poet may quite faithfully describe it as yawning. There may be no better word in the language to describe what it looks like, so this is another sort of truth about it.

But if you, on your part, prefer to look at it in the

second way, you may feel that the only really important thing is that it was used by smugglers to hide casks of brandy. Well, which is it—a yawning cave, a smugglers' cave or a sea cave? Of course, they are all equally true descriptions, but one concerns its appearance, the next its use, and the third its cause. Its cause is certainly no more important than its appearance or its use—probably less so to most people.

Though we should not confuse these three ways of looking at the landscape, this does not mean that we may not use all three at the same time. This is what I have tried to do sometimes in this book, though it is nearly all about causes, for the reasons I have given. The other ways receive most attention in the last chapter, but they are prepared for right at the beginning of the book—to which I hope you will now turn.

W.S.

1

Peeping Behind the Scenes

WHEN Shakespeare wrote 'All the world's a stage', he was not thinking of the scenery, but in this book we are going to look at the countryside around us as if it were the scenery on a stage. We shall not only admire it, but also find out what it is made of, where it comes from and what props it up. When we look at a hill or a valley, or across a plain, we see only the grass and trees that cover them. But underneath their green covering there lies the real hill or valley, carved in great piles of rock which may be thousands of feet thick.

These piles, with their many supports and buttresses, are like the beams and timbers that hold the stage scenery up. The things that we actually see are like the paint which decorates it and the curtains which drape it. Or we may prefer to think of them as 'stage-props' and dressing-up clothes, for is not the very turf on which we walk but a sort of close-fitting green vest which the rocky ground wears for our benefit?

There is nothing new in this idea that the things we see in a landscape are a sort of clothing on the earth, or a scene painted on the rocks. Henry Howard, who was Earl of Surrey in the sixteenth century, wrote that the spring

With green hath clad the hill and eke the vale,

and there must be few who have not at some time compared the many-coloured fields of an English landscape to a patch-work quilt.

Dante thought of the landscape in terms of paint, and so the spirits in the *Inferno* are seen walking about on the 'green enamel' instead of the grass. When Dante (in his second book) describes the flowers sprinkling the lawn, instead of naming their colours he gives a list of the actual paints that were then used for illuminating manuscripts—'Gold, and fine silver, and cochineal, and white lead, and Indian wood, serene and lucid, and fresh emerald' (the green pigment, not the precious stone). Milton, too, refers to the fruits and flowers of Paradise, peeping over the wall, as if they were painted decorations of the scenery—'with gay enamelled colours mixed'.

In the last chapter of this book we shall look carefully at all the separate colours with which the scenery is decorated, but our first job is to 'peep behind the scenes' and examine the rocky framework on which it is exhibited—'this goodly frame, the earth', as Hamlet called it. We shall try to see why one hill has one shape and another a different one, why one river tumbles over a waterfall while another forms a lake, and why there are cliffs at some seaside places but not at others. Such questions as these will take up most of our time, but their answers will help us to understand why the final decoration shows the patterns and colours that it does.

The shaping of the rocks into the various forms of landscape is more often like the work of carvers and sculptors than that of a stage carpenter, and there is

building work to be done, too—cement and concrete mixing and the making of slates and flagstones. The variety of jobs is endless, and the names of the chief workmen are Fire, Water, Ice, Frost, Snow, Sunshine and Wind. The tools they employ include sharp stone chisels, hammers made of rock, sand-blasts, wedges and rock-drills, and they also make use of compressed air, steam, acids, gases, and even microbes and the roots of plants. The hills and valleys, the plains, the cliffs and beaches, all have to be chipped, sawn, hammered, axed and chiselled out of the bare rock, and we are going to watch all these things being done.

But before any of this work can start, the raw material of rock must be heaved into place. If the world were a smooth round ball there would be no *land*scape to look at at all, for the water would cover the entire earth to a depth of about one and a half miles. If we are to have a landscape the rocks must be raised above the sea, at any rate in some places, and the higher they are raised the more material will the workmen have to use.

The important job of raising the land is done by the earth itself. The earth is very hot inside and in some places the rocks have actually melted. Molten rock can flow like water, but even if it is only softened it can still move. Very great pressure can make it move slowly even when it is quite solid, and deep underground the pressure can be truly enormous. In some places it is greater than in others, and so some of the rocks are always trying to push the others out of the way. When they push hard enough the rocks move, and movements of this kind are always going on in and beneath the earth's crust.

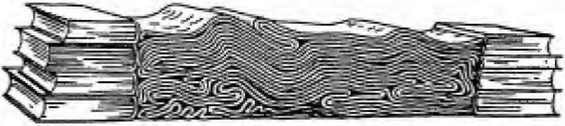
The rocks move very slowly, perhaps less than an

inch in a hundred years or more, but as they move they disturb the surface of the ground, sometimes raising it and sometimes lowering it. Most of the rocks near the surface are found spread out in thin sheets, or layers, one on top of the other like blankets on a bed. When the deeper rocks move it is as if there were somebody in the bed slowly turning over. The blankets are raised in one place but sink in another. In a somewhat similar way the earth manages to raise parts of its surface high above sea-level, heaving up great masses of rock as big as whole countries and getting them into positions where the landscape-carvers can get to work on them.

Let us now take a closer look at these movements as they appear on the surface. There are two ways in which the layers of rock can be lifted up. They can come up flat and level, as if raised by a lift, or they can be bent up in great folds. They bend or 'buckle' up when they get squeezed between vast blocks of rock that are moving slowly towards each other, and you can see how this happens by doing a simple experiment.

Lay a flat pile of several pieces of cloth on a table between two piles of heavy books. The pieces of cloth represent the layers of rock composing the earth's outer crust. If you now push the two piles of books slowly towards each other, so as to squeeze the cloth between them, the layers will bend into waves or folds, some of them rising so high above the surface that they may actually flop over. This is illustrated in Fig. 1.

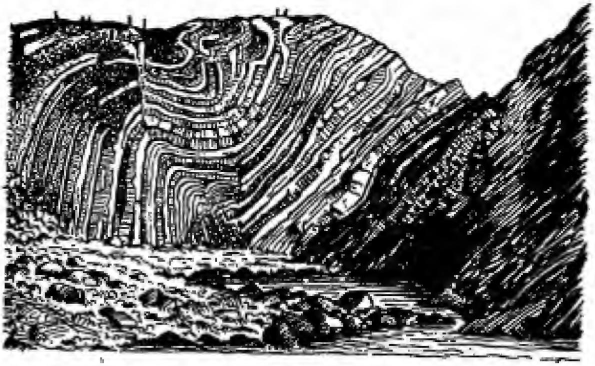
It may surprise you that such a hard substance as rock can be bent in this way, yet it can happen if sufficient force is used very, very slowly. When the St Gotthard tunnel was being driven, the engineers



1. A pile of cloth patterns used to show how the layers of rock may become folded by being squeezed between two blocks.

set a row of iron posts into the rock to mark a perfectly straight line. But after some months the posts were seen to have shifted slightly as the rock of the mountain slowly adjusted itself to the new stresses caused by boring such a large hole in it. It was seen that the rock had not cracked, but had *bent* under the weight of the mountain!

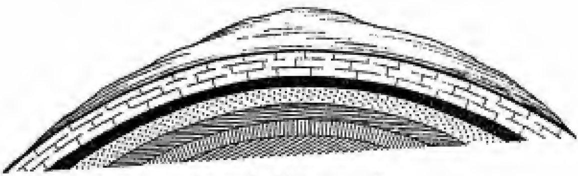
In cliff-faces you can sometimes see how the layers of rock have been folded exactly like the layers of cloth, sometimes even standing on end or falling right over so as to lie upside-down. Look at the example in Fig. 2. It must have taken many millions of years to



2. Beds of limestone and shale folded and buckled up at Stair Hole, on the Dorset coast, England.

produce these folds, and it is not surprising that some of the beds of rock have cracked while being bent. You can see some of these cracks in the picture; they are called 'joints'.

Whether the land has been raised like a lift, so as to keep level all the time, or whether it has been buckled up into folds as if by a bulldozer, as soon as it becomes exposed to wind and weather the carpenters and carvers get to work on it and cut it into all sorts of fantastic shapes. You might think that a single huge fold would itself make a mountain, as in Fig. 3, but this kind of 'fold-mountain', as it is called, is rarely



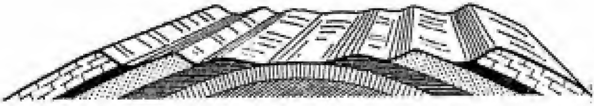
3. A simple fold-mountain.

met with. The carving usually goes on nearly as fast as the rock comes up, so that by the time the fold *should* have reached the height of a mountain it has already been cut into a whole landscape of smaller hills and valleys.

These may seem to have very little to do with the shape of the fold itself, yet the kind of landscape produced does depend on the folding to some extent. This is because the different layers of rock are not all equally hard. If there is a sharp fold, for example, as soon as the top has been removed by the weather the layers are exposed standing on end, and then the carvers will get to work much more quickly on the

soft layers than they do on the hard ones. The result is shown in Fig. 4, where you can see that the top of the fold, instead of making a mountain, is lower than the hills on either side.

This will help to show you why so few mountains are simply a mass of rock raised to a great height. The land must, indeed, have risen, but the mountains we see are nearly always what is left after most of it has been removed again. The only difficult thing to pic-



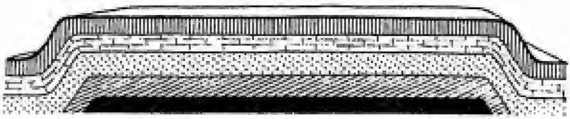
4. A fold with the top weathered away, showing how the layers of hard rock make ranges of hills.

ture in this is that the removals go on right from the start, so that the land never really does get as high as we should think was necessary to bring all these changes about.

If the layers of rock are not folded, but come up in a level position like the roof of a lift, they are attacked by the weather in the same way but produce quite a different kind of landscape. Any soft rocks on the top soon get worn away, but the first level 'table' of hard rock to become exposed will protect all the rocks beneath it like a great, flat umbrella. Instead of a landscape of mountains and valleys we shall have—at any rate, for a long time—a wide stretch of high, flat country. This is a 'table-land', or 'plateau', and it is illustrated in Fig. 5.

Yet a plateau of this kind may get cut up into

mountains eventually, because even the hardest rocks will wear away in time, especially if there are cracks in them—as there nearly always are. The cracks expose the softer rocks beneath, and once the carvers get access to those they work rapidly and soon widen the cracks into deep valleys. And as the deep valleys appear—why, there are the mountains standing up between them!



5. A plateau produced by the level rising of flat beds of rock.

Have you ever thought of that before—you cannot have a mountain without first having valleys? Yet it is easy to see that *two* mountains cannot exist side by side unless there is a valley between them, for if there is no valley between, then there is only *one* mountain! Now, because most mountains are thus the result of valley-carving, which is done by rivers, we shall describe the work of rivers before we look more closely at the various kinds of mountain. This may strike you as odd, for we commonly think of rivers as being born in the mountains and not of mountains as the products of rivers. Yet both ideas are equally true; it just depends on your point of view.

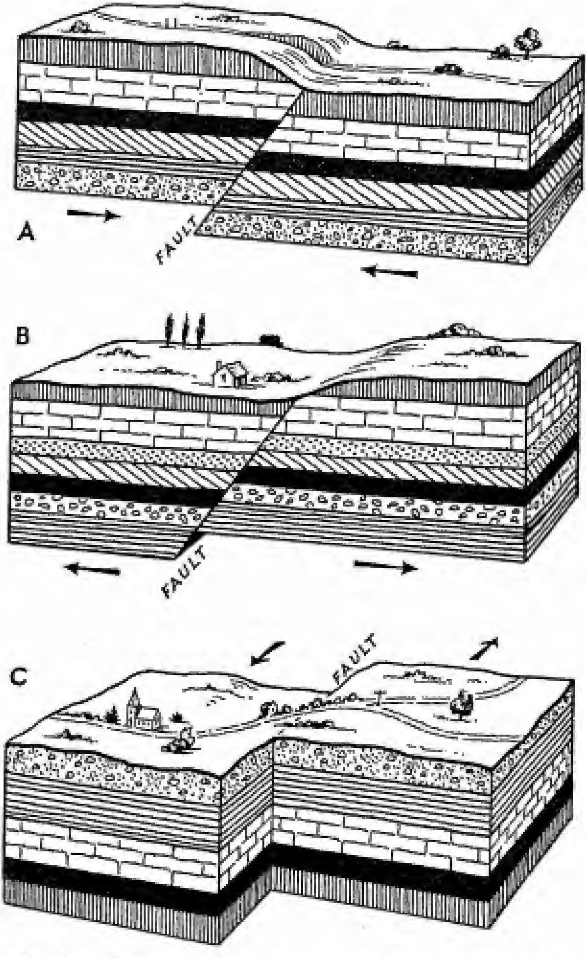
We shall come to the rivers, then, in the next chapter. Here, we have been peeping behind the scenes to see what goes on before the curtain rises, and we still have a few more stage secrets to divulge. We shall not, however, spend more time than is really

necessary on these hidden activities, for we are chiefly interested in what we can actually see going on when we look at the scenery from the front. After all, it is only there that we can play our parts as observers, sketchers, photographers, collectors of pretty stones—or perhaps just as picnickers.

The few remaining secrets back-stage are concerned chiefly with the accidents that may happen there. The folding of great thicknesses of rock and the raising of plateaux are tremendous operations, liable to a number of serious mishaps. Though the stage-carpenters hide them as well as they can, and the scene-painters quickly cover them up, they often show from the front as odd shapes in the scenery and may even cause part of it to collapse.

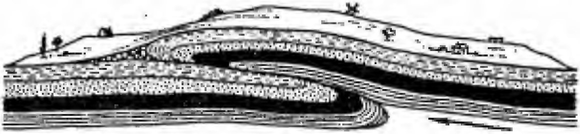
We have already seen that the rocks sometimes crack when they are bent too far or too quickly, and so show 'joints'. It may also happen that quite thick layers crack and slip badly out of line, and this produces what is known as a 'fault'. There are many different ways in which this can happen, but they are all variations of the three sorts of slipping shown in Fig. 6. Can you see the difference between them? In A, the break has occurred because the rocks have been pushed together too hard, so that the left-hand part has tried to slide up and over the right-hand part. In B, the blocks have been pulled apart so that the left half has slipped down a little. (Otherwise, there would have been a gap.) In C, the blocks have been dragged or torn apart sideways. The arrows show the directions in which the rocks have moved.

Sometimes the rocks are pushed together with such force that one side of a fault is carried right over and on top of the other side. This is called a 'thrust' and



6. Accidents that may happen. In A, the left-hand block is forced to slide up over the right-hand block, but in B it slips downwards. In C there is a sideways movement on the same level, producing a 'tear' fault.

how it happens is illustrated in Fig. 7. In this way, one set of rocks may get pushed over the top of another set for several miles. As you can imagine, the edge of a fault or thrust often forms a sort of ledge or ridge which shows up in the landscape, though you cannot say that any particular ridge has been caused in this way unless you can actually see the rocks, for there are several different ways in which ridges may be formed.



7. Another accident, in which the beds of rock have been first folded over and then those on the right pushed over the top of the beds on the left, producing a 'thrust' fault.

Faults usually develop very slowly. The rocks first crack and then move perhaps less than a hundredth of an inch. They may take a thousand years to move a few inches and nobody is aware that they are slipping. Occasionally, however, they may slip suddenly a fraction of an inch and then there is an earthquake. There are two large cracks in the clay beneath London, and in 1750 these slipped a little with disastrous results. John Wesley was there and described what happened in his diary.

'There were three distinct shakes, or wavings to and fro',' he wrote, 'attended with a hoarse rumbling noise, like thunder.' Several houses were shaken down, chimney-pots came crashing to the ground and stones fell from Westminster Abbey. In 1884

another earthquake, caused by a fault across the mouth of the Thames, damaged 1,212 houses! In these examples the rocks probably slipped less than one-sixteenth of an inch, and they show how serious even a slight accident of this kind may be.

In other countries, where the rocks are under a much greater strain and may slip several feet, whole cities may be completely destroyed by earthquakes. Such shocks have occurred many times in America, India and Japan, the collapse of the houses often being followed by devastating fires. In 1906, San Francisco was almost completely demolished by a severe earthquake, caused by a slip along a great fault nearly a thousand miles long. The rocks on one side of it moved along for a distance of twenty-one feet in a series of jerks that brought most of the buildings to the ground.

The record movement seems to have occurred in Alaska in 1899, when the coast was hoisted vertically upwards to a height of forty feet! In other earthquakes there is a different kind of movement, and the ground suddenly gapes wide open to swallow up anything standing on the surface. The gap may then close up again, crushing everything that has fallen into it. A Japanese earthquake of this kind is illustrated in Fig. 8.

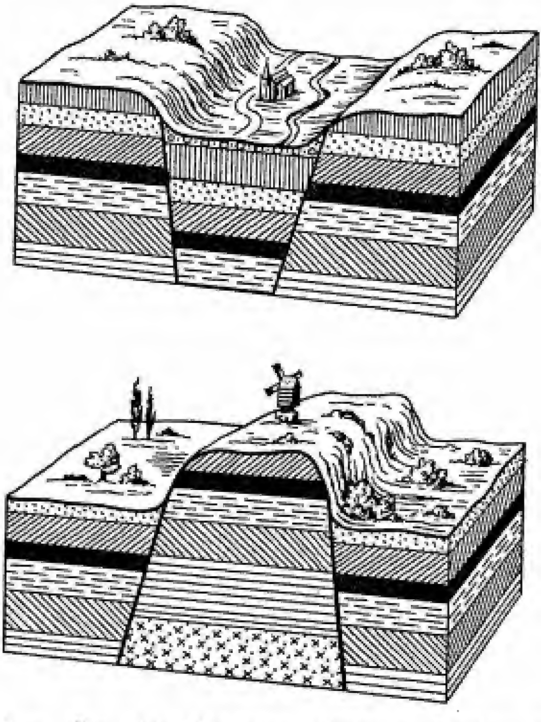
Most of the lands of the earth are criss-crossed with faults that have developed slowly and without disturbance, and these have sometimes given rise to landscape features of special kinds. For example, a small area of land may find itself completely surrounded by cracks, and it may then sink below the surrounding country or perhaps get raised above it. A tract of land that has noticeably dropped between

8. A dramatic scene during an earthquake at Akita, Japan. When the road began to gape open planks were put across to enable people to escape from the danger zone. Then a second shock produced a much wider gap, which this man is having to jump over. This part of the road was completely destroyed.

two faults is known as a 'rift-valley', and one that has been raised is called a 'block-mountain'. These are illustrated in Fig. 9, but they do not form common features of the landscape. They are given here to show the sort of result this kind of accident can produce in the scenery.

Another kind of accident altogether is caused by events which take place deeper down in the earth's crust, where it is hot enough for the rocks to melt. An underground reservoir of molten rock may come under enormous pressure from the weight of the rocks above it. This forces the liquid rock into all the cracks and joints around the reservoir, and some of it may

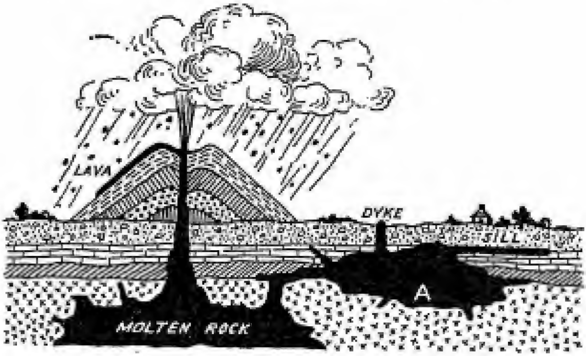
work its way upwards until it actually comes out on the surface. Here, it may pour over the countryside in a flood of red-hot lava, or it may squirt up in a kind of monstrous fountain called a 'volcano'.



9. *Some effects of double-accidents.* Above, *a rift-valley, or 'graben'*; below, *a block-mountain, or 'horst'*.

The molten rock of the fountain cools rapidly in the air to form cinders and fragments of rock of all sizes, and these fall to the ground in a heap all round

the opening, or 'vent', of the volcano. The heap may soon be as big as a mountain, with the fountain still playing out of the top. In coming out, the molten rock widens the mouth of the vent to form a saucer-shaped 'crater', which sometimes fills with lava and overflows. Wherever the lava flows it burns and destroys everything in its path. And you may have read how the dreadful rain of ashes and rock-fragments from the great eruption of Vesuvius, in A.D. 79,



10. A section through a volcano. The different parts are described in the text.

completely buried the Roman city of Pompeii. A typical volcano is illustrated in Fig. 10.

Rocks that have come out of the earth in a molten state, whether as a sheet of lava or in the form of fragments, are called 'igneous' rocks, from the Latin word *ignis*, meaning fire. They look quite different from the common rocks that are found spread in layers over most of the land. Lavas sometimes cool to make a sort of black glass, but they are often so full of small bubbles of gas or steam that they

form a kind of stony sponge called 'pumice'. Very likely you have a piece at home for rubbing stains off your fingers. Very thick masses of lava usually cool into a heavy black rock which looks like iron. This rock is very hard and is called 'basalt' (pronounced *bass*-awlt).

In some places the molten rock has been unable to make its way to the surface of the ground, but has cooled to form great shapeless masses of igneous rock while still deeply buried. See Fig. 10 at A. Such masses, which are generally of some sparkling rock like granite, often lie buried for millions of years, but in the end the overlying rocks may get weathered and washed away so as to expose them to view. Because they are very hard they generally stand out above the surface as huge knobs, or 'bosses', which may be as high as mountains and as big as counties.

Such bosses of igneous rocks get slowly carved into valleys and peaks, like other high land, but they generally keep their 'knobbly' character right to the end. The whole of Dartmoor, in south-west England, is one such carved granite knob, and a smaller one, in South Dakota, U.S.A., is illustrated in Fig. 11. There is a famous group of them in the Henry Mountains, in the State of Utah, and they are to be found, here and there, in most of the countries of the world.

Between these two extremes—the lava on the surface and the massive granite that forms deep underground—we sometimes find thin sheets of igneous rock that have forced their way between the layers of ordinary rocks, like slices of meat in a sandwich. They are called 'sills' and are generally made of basalt. Often the basalt fills up the vertical cracks in the rocks

as well, standing up like buried walls. These are called 'dykes', and both dykes and sills are shown in Fig. 10.

The rocks that are not formed from the molten state—that is, the rocks that are found in layers, like clays and sandstones—will be described in later chapters as we come to them, but as they are nearly all formed from sediments that originally settled down in water they are known as 'sedimentary' rocks. This

11. Black Hill, S. Dakota, U.S.A., a mountain of igneous rock. Note the broken beds of limestone forced up on either side.

distinguishes them from the igneous rocks. The layers in which they settle are known as 'beds' or 'strata' (which is Latin for layers), and in this book whenever we mention strata, or beds—or folds, or faults—we shall always be referring to sedimentary rocks of one kind or another.

This completes our preliminary 'peep behind the scenes'. We can now picture the country as covered chiefly with great sheets of sedimentary rocks, sometimes folded and sometimes cracked by faults, but here and there broken into by knobs or bosses of igneous rocks that have come pushing up from

below. On this sort of background the landscapes that we see have been carved by Water, Ice, Frost and all the other agents we have mentioned, assisted from time to time by slow movements in the crust of the earth.

2

The Part Played by Rivers

The rocks that have been raised above sea-level are of many kinds. Some are as hard as iron; others are as soft, almost, as the sea-shore sand. But even the hard rocks are often cracked and jointed, and when rain falls a great deal of water finds its way underground.

The thirsty earth soaks up the rain,
*And drinks, and gapes for drink again.**

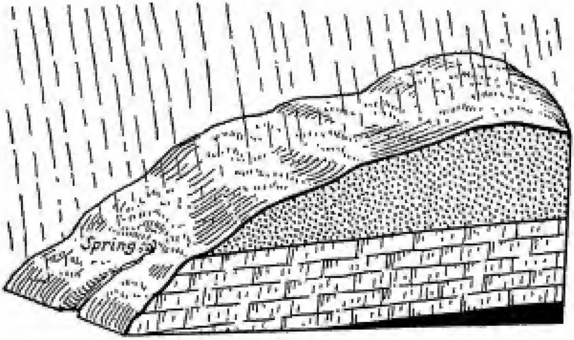
The water may percolate a long way down, trickling through cracks or soaking through softer rocks, but sooner or later it meets a layer of stiff clay, or perhaps an unbroken sheet of hard rock, that prevents its going any farther. At such depths it cannot dry up, any more than it could in a bottle, and after every rainy spell more water comes down to join it. Eventually, the deep rocks become as full of water as a sponge.

When the rock contains as much as it will hold, the water seeps sideways until it presently reaches the open air in the bottom of a cleft or on the side of a slope. Here it bubbles out as a spring and runs down the slope as a tiny stream. See Fig. 12. Some springs cease to flow after a time because all the water has

* Abraham Cowley, *From Anacreon*, ii, *Drinking.*

been used up, and they do not reappear until there has been another spell of rain on the rocks above. They are then called 'intermittent' springs and the little rivers that flow from them after wet weather are known as 'bournes'.

There are many quaint local names for bournes, particularly in the old villages of England but also in countries where the English settled in the seventeenth



12. How springs are made. The rain soaks through the mountain until it comes to a layer of rock through which it cannot pass. The water comes out at the level where this rock meets the mountain-side.

and eighteenth centuries. In some places they are called 'winterbournes', in others 'nailbournes'. When the rocks always seem to look dirty except when the bourne is flowing it may be called a 'lavant' (from the French *laver*, to wash), but if it springs sometimes from the rocks at one place and sometimes from another, it may be called a 'gypsey'—because it seems to wander about. Such names are interesting to make a note of when you come across them, but

they all mean the same thing—an intermittent spring with the stream that flows from it.

But it often happens that the rocks hold so much water that there is enough to keep a spring flowing even through the dry season. It never dries up and so is called a 'permanent' spring. Because water always runs downhill, the little stream that flows from it seeks out the lowest places and soon washes out a little channel for itself. As it travels along it is joined by the streams flowing from other springs and presently becomes big enough to be called a river. It goes on flowing downhill, getting larger and larger, until at last it reaches the lowest part of the land—which is generally where it dips under the sea.

That is a brief outline of the story of a river, but its journey may take it many hundreds of miles and on its way it meets with many adventures. Of these we shall now tell, and though most of the things that happen take place very slowly they have such big effects on the landscape that you have probably noticed them hundreds of times without realizing their cause. They start right at the beginning of the river, among the springs from which it flows.

Because most of the rain falls on the highest land springs are very common on the slopes of mountains or the sides of a plateau, and their streams begin their journey by a more or less steep descent. The water flows swiftly and quite easily scours out its little channel by washing away the soil, but if you look carefully you will notice that it does much more than this. On its bed you may see pebbles of rock, some angular and some smooth, and every now and again one gets overbalanced by the rushing water and tumbles forward. A fresh pebble thrown into the

water may get trundled along for several yards before coming temporarily to rest against a piece of rock.

Now, the little stream is always receiving a fresh supply of pebbles. They may be split off the rock of the mountain by frost (in a way to be told later), or the roots of plants growing on the bank may work their way into cracks in the rock and wedge pieces off by simply growing fatter. This you may find hard to believe, but the force exerted by growing vegetation is always astonishing. In Cheapside, a busy street in the City of London, there was once a lot of trouble because the heavy flagstones of the pavement were pushed up several inches by mushrooms trying to come up for light and air! If you keep your eyes open you will often see walls split asunder by the roots of quite small, tender-looking plants, as well as by those of trees.

At all events, our little stream is being continually supplied with stones, but it never gets filled up with them because they get carried away by the water as fast as they arrive. A stream travelling at only two miles per hour can move stones the size of a hen's egg along its bed, if it is fairly smooth, and our mountain stream is moving much faster than that. The stones, too, tend to tumble downhill themselves unless they are prevented, and if we could take a film of our river-bed and then run it through the projector at, say, ten times the proper speed, we should see a whole crowd of stones clattering along like people rushing to catch a train.

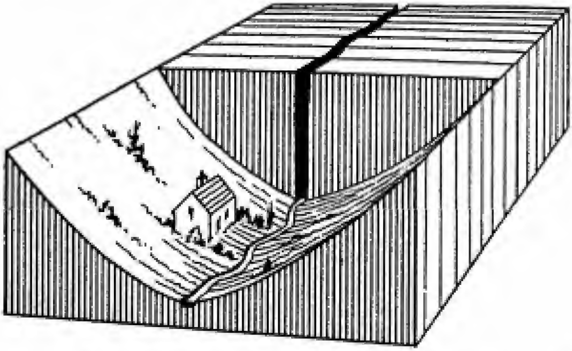
Now, the river, you may remember, is one of our workmen, and these stones are its tools. As they are trundled along they not only knock each other's corners off, and so become round and smooth, but

they also wear away the rocky bed of the stream. This is a slow process but it may go on for tens of thousands of years, and all the time the bed of the stream is getting deeper and deeper. This is called 'down-cutting', and in a moderately rainy country the swifter rivers may lower their beds at the rate of a few inches every century. In particularly soft places, or during floods, they may work much faster, but even at this rate it means that after twenty thousand years they will have cut downwards into the rock to a depth of thirty or forty feet—which is higher than a three-storey house.

Almost all the streams we are likely to come across must be at least as old as that, so you will wonder why they are not running along the bottoms of narrow ditches at least thirty feet deep! The answer is really quite simple. As the ditches are being dug their sides fall in. You see, the sides, or banks, of the river are usually broken up into loose soil by growing plants, and they are exposed to wind and weather. They cannot stand up like brick walls (though even brick walls wouldn't stand up for twenty thousand years). So they crumble and fall, and soon become steep slopes down which the rain flows in runnels at every shower. Loose stones and soil on these slopes get washed down to the river, so that the slopes themselves get less and less steep until they presently form a wide, V-shaped valley with the stream flowing along its narrow bed at the bottom.

If you stand to one side and consider this valley, you will soon see what a tremendous amount of work the stream has really done. Look at Fig. 13. This shows a block of land cut into by a river, but in one half it flows along a deep ditch and in the other

along the bottom of the valley it has made. You can see what an enormous amount of rock the river must have removed in order to make that valley. Its down-cutting was, after all, only a small part of its work. The whole rock-removing job is called 'valley-carving' or 'river erosion', and it is one of the most important processes in the shaping of landscapes.



13. This little river must have removed an enormous amount of rock to make its valley. At the back of the diagram the rocks are imagined put back, to show their quantity.

But rivers cannot always achieve so much. When the rocks are very hard and the river very swift, the down-cutting may go on much faster than the valley can form. The river may then cut itself a deep gorge with vertical or even overhanging sides. This is especially likely to happen where the beds of hard rock have been cracked by a fault. When the fault was produced, the movement of its two sides against each other crushed and ground up some of the rock, and so left a line of weakness along which a stream

could quickly cut a deep channel. It does, in fact, widen and deepen the crack of the fault.

Deep gorges may also be produced in soft rocks by rivers which happen to cross deserts, but for a different reason. Here, the down-cutting need not be especially rapid, for the sides of the gorge will remain standing simply because there is no rain to wash them in. Such gorges are called 'canyons' (Spanish *cañon*,) the best-known and biggest in the world being the Grand Canyon of Colorado, which is more than a mile deep.

With most rivers, however, the two processes of down-cutting and valley-forming go on together. In the upper reaches of the river, where the water runs swiftly, down-cutting proceeds very rapidly and the valley-sides are steep. Even near the original springs, where the water gushes out, the bed of the stream will soon be lowered, and then the water may have to begin its travels by dropping several feet in a waterfall. But more often something much more interesting happens.

Just as the sides of the valley gradually fall in and get washed away, so does the rock and soil over the spring itself. The steep sides soon become slopes, and the place where there might have been a waterfall becomes a slope at the head of the river, too. The spring now appears farther back, for the mountain is actually being cut into by the river. When this has happened the river is said to have 'cut back its head', and in this way many rivers get longer as they grow older. The process is called 'headward erosion'.

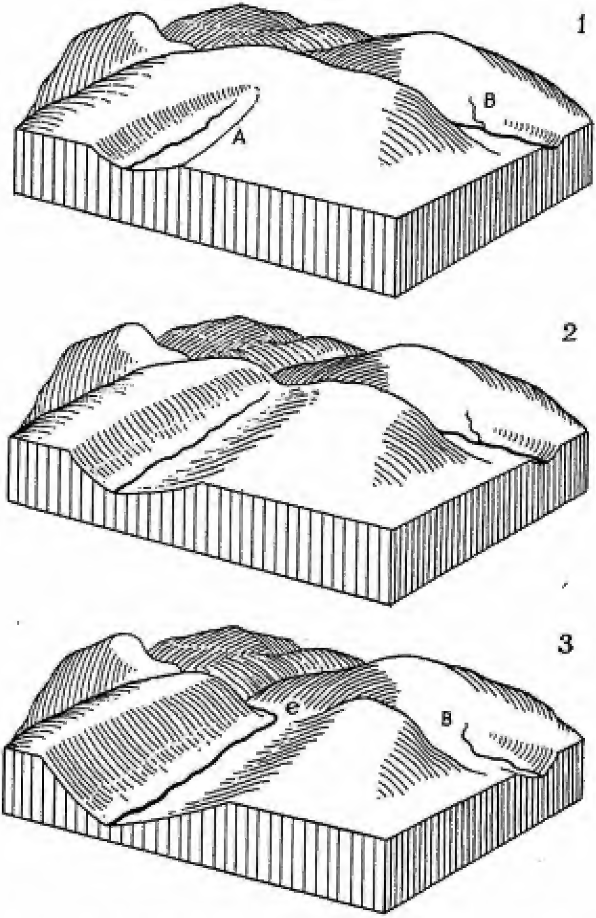
You will naturally wonder how far back into a mountain a river can cut. The answer may surprise you. It is that a river may, and often does, cut right

through the mountain and invade the valley of another river on the other side of it! In Fig. 14, river A is deepening its valley much faster than river B, and in the second diagram it has begun to breach the mountain. The head of its valley now forms a sort of notch in the mountain, called a 'saddle', 'col', or 'wind-gap', and travellers who wish to cross the mountain will probably make use of it as a 'pass'.

The third diagram shows how the river eventually cuts the mountain into two and steals the water from the upper part of the river B. This is called 'river-capture', and B is said to have been 'beheaded' by A. All that is now left of B is the tiny stream on the right. Because it is in a valley much too big for it, it is called a 'misfit' or 'underfit'. The corner at *e* is known as the 'elbow of capture', and the old valley behind the right-hand mountain between *e* and B has become a 'dry valley'. You do not need to learn all these terms—they are so beautifully descriptive that you simply cannot forget them.

All that we have said of rivers so far (except for the bit about canyons) applies to their upper reaches, where they are usually swift mountain torrents and are vigorously engaged in down-cutting and washing away enormous quantities of rock, stones and soil. This part is often called the 'torrent tract' of a river, but when it leaves the high mountains and begins to flow over more level ground it slows down considerably and goes through a completely different set of adventures.

By this time it will have been joined by more streams and so it is larger, but because it moves more slowly it does less down-cutting. The valley-forming, however, goes on as before and so the sides of the



14. An act in the play in which one river captures or 'beheads' another. Scene 1 shows the two rivers separated by a mountain. Scene 2 shows the river on the left 'cutting back its head'. In Scene 3 it has cut right through the mountain and stolen the head-waters of the other river.

valley become less steep. But there is another consequence of its slowing down, and this is that it can no longer move such large stones along its bed. Those it has brought down from the mountains come to rest, and only the smaller pebbles and sand-grains get carried on.

The amount of solid material in the form of pebbles, sand and mud that the river can keep on the move is called its 'load', and this varies with the river's speed. If the water is very nearly still, almost the whole of the load will settle down. This is called 'deposition' and it is the opposite process to erosion. In its torrent tract the river moved swiftly and its work consisted wholly of erosion. Now that it is going more slowly there is less erosion and a certain amount of deposition. This stage of the river's course, where erosion and deposition go on side by side, is called its 'valley tract'.

If the river is carrying its full load, for every new handful of sand or mud it picks up it must drop an equal amount of what it held before. It is just as if you had your two hands full of stones and then wanted to pick up a new one; to do so, you would have to let go of one you already held. The river generally picks up the finer and drops the coarser material as it goes along, so that if you walked downstream along its bed for several miles you would find the pebbles, on the whole, getting smaller and smaller as you went. That is to say, you *would* find it so if it were a very well-behaved river.

Few rivers are, however, well-behaved. They turn this way and that, seeking out the lowest ground, and sometimes they put on speed over a rapid, or slow down so as to come nearly to a standstill. On occasion,

they may even choke themselves by dropping their load too suddenly, and then they overflow and flood their own valleys. It is these tricks that a river gets up to in its valley tract that we are now going to watch.

No natural river ever flows for long in a perfectly straight line. It picks out the lowest ground, which is generally the softest ground, flowing round any hard rocks or mounds that lie in its path. Now, once it has started to flow in a curve, however slight, some very interesting things begin to happen.

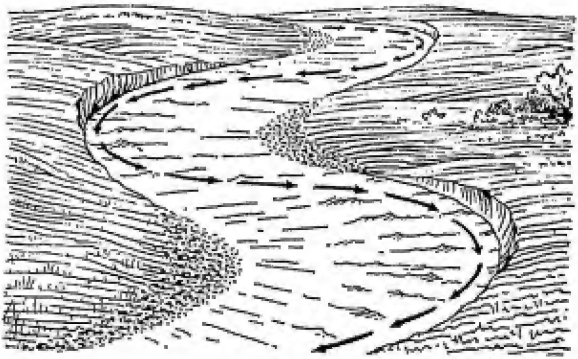
Just suppose, for a moment, that instead of water flowing along a river-bed we have a regiment of soldiers marching along in four columns. What happens when they are ordered to 'right wheel'? The column on the right side—that is, the inside of the curve—takes very short steps, almost marking time, while the left-hand column—on the outside of the curve—takes extra long steps to get round the wider curve in time. Those that go the longest way round have to go faster.

If you now think of the water in a river, instead of the soldiers, you will see that on any curve the water on the inside has to slow down a little, and the water on the outside to speed up, if the river is to flow smoothly round the bend. Several things happen as a result of this.

First, think of the swift water swinging round the outside of the curve. Because it is moving in a circle it tends to get flung outwards, just as a stone on a string tends to fly outwards when you swing it round. This causes the water on the outside of the curve to scour away the outer bank and carry some of it away as mud and loose stones. But on the inside of the curve the water is travelling extra slowly, so here

it drops some of the load it was already carrying and deposits a small beach of mud or sand—or the small pebbles we commonly call 'gravel'.

If you look at Fig. 15 you will see that the effect of this is to increase the sharpness of the curve. The outer bank is pushed farther out still and forms a sort of cliff, which is being continually undermined, while the inner bank grows out into the stream by the

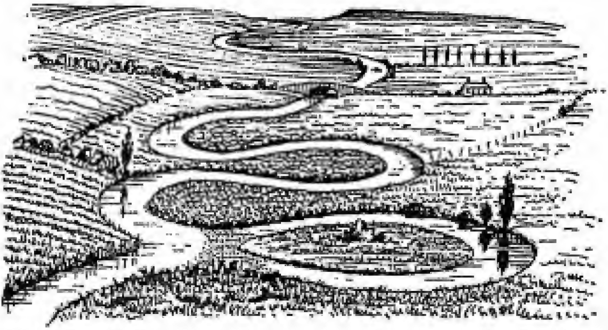


15. A winding river scoops out cliffs on the outside curves but deposits sand and gravel on the insides. The arrows show the path of the most swiftly-moving water.

deposition of a beach. Again, the water on the outside is moving swiftly and so begins to do some down-cutting as well, and the result is that the river becomes deep on the outside of the curve but shallow on the inside.

The water rushing round the outside may even eat its way into the side of a hill and make quite a high cliff, which is called a 'bluff'. The wide shelving beach forming on the other bank rejoices in the queer

name of the 'slip-off slope'—which helps to describe it, though you may think not very well. The whole curve is called a 'meander', after the river Meander in Greece, which is noted for the way in which it winds about. You can see these things happening quite clearly in almost any small stream where it flows in a curve—and even, sometimes, in the little runnels of rain-water flowing over a sandy road.



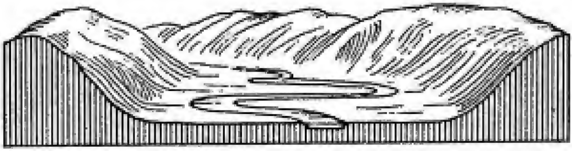
16. A scene in which a river winds round until it meets itself. The loop which has been cut off forms an ox-bow lake with an island in the middle. Note how the lake is now separated from the river by deposits of sand and gravel where the still water begins.

Once a river starts to meander, then, it tends to flow more and more in a curve, and presently it may perform a complete circle and come round to meet itself. This sounds extraordinary, but Fig. 16 shows how it happens. When it has met itself in this way, the water takes a short cut and stops flowing round the meander any more. This now forms a sort of back-water called an 'ox-bow lake'.

Now, one of the most interesting things to notice

about meanders and ox-bow lakes is that, in order to produce them, the river has to travel sideways across its valley as well as down it. In doing so, it continually drops material on the slip-off slopes, so that in the end, though the river itself may be only a few yards across, it can have widened its valley by several hundred yards and carpeted it all with sand and gravel.

The gravel is spread sideways across the valley not only at the positions of the meanders, for the river as a whole is pushing its way down the valley all the



17. The windings of a river widen the floor of its valley, producing a flat 'flood-plain'.

time and taking its meanders with it. So we often find a river winding across a wide plain of continuous gravel, much of which is now a very long way from the water which deposited it. The river-valley no longer has the simple V-shape illustrated in Fig. 13, but has the form shown in Fig. 17.

The whole process is called 'valley-widening', and the flat bottom is called the 'valley-flat' or 'flood-plain'—because in very wet weather the river may overflow its banks and cover the whole valley with a foot or two of water. When this happens the water over the plain is very still and drops even its finest mud. This makes the plain very fertile and lush grass

will later grow on it and make rich meadows. Such meadows are often criss-crossed with artificial drainage channels, intended to control the flood-water, and then they may be known as 'water-meadows'.

Now for another sort of adventure. A river may flow for many miles across a highland of fairly hard rocks, and then suddenly come to the end of it. It plunges over the edge as a waterfall and then continues on its way across the softer rocks at the foot. The water falls quite fast and lands at the bottom with a great splash and considerable force. This enables it to do a lot of cutting work, using loose stones and pebbles for tools. It may scour out a fairly deep hole where it strikes the softer rock, for the water here swirls about in violent eddies and sometimes goes round and round several times before it gets clear away.

Pebbles are liable to get caught in some of these eddies, and get whirled round and round by the water. They may soon grind or 'drill' out a hollow like a saucepan or deep bowl in the rock of the bottom, and there they will stay—for all the world like eggs being boiled. Such little hollows are called 'pot-holes',* and you may often find them at the foot of a waterfall, even if some of them have lost their stones.

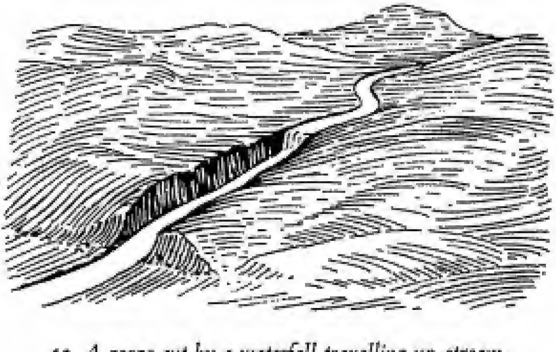
But all this to-do at the bottom of the fall has its effect on the cliff over which the water is plunging. Not only is the bottom worn rapidly deeper but the foot of the cliff, too, is attacked. It becomes under-

* This is the proper use of the word 'pot-hole'. People who explore underground caves call themselves 'pot-holers' but this is a journalistic use of the word and really has nothing to do with pot-holes.

mined and presently the rocks at the top lose their support and come tumbling down. See Fig. 18. This sets the waterfall back a few feet, but the process is repeated in the new situation so that the waterfall gradually moves upstream. This is another case of headward erosion, and it may remind you of how a river cuts back its head, as we described on page 37.

18. A waterfall which undermines its own cliff and gradually travels up-stream.

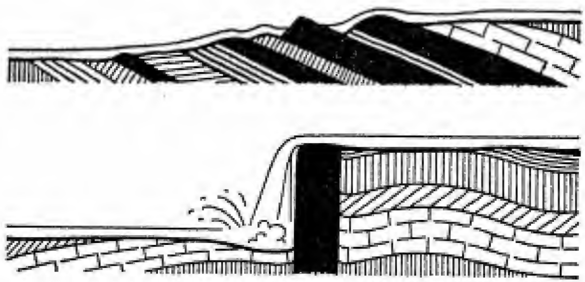
For the river we have been describing, 'upstream' means back into the higher land from which the water fell, so that as the fall recedes it leaves a deep gorge in hard rock in front of it. All such waterfalls are liable to cut gorges in this way, which is illustrated in Fig. 19.



19. A gorge cut by a waterfall travelling up-stream.

The famous Niagara Falls, in America, are cutting their way upstream at a rate of three or four feet every year, and have so far cut a gorge seven miles long and two hundred feet deep.

For a waterfall to recede as quickly as this the rock at the foot of the fall must be soft enough to wear away much more quickly than the hard rock above. This happens when, as in the case of Niagara, the layers of rock are horizontal. But two other positions



20. Cataracts or rapids (above) *may be formed when sloping strata of hard rock project into a river-bed. A vertical bed or 'wall' of hard rock may produce a waterfall that remains in the same place for a very long time.*

for them are possible. The layers may be sloping at an angle or they may be standing upright like a wall. These arrangements are illustrated in Fig. 20, and it is at once clear that if the hard rock stands up vertically there can be very little undermining, and the waterfall will remain in the same place until the hard bed itself has been worn right through. This may take thousands of years, especially if the hard wall is a dyke of basalt (page 29).

When the beds of rock are sloping (in either direction) we do not generally get a waterfall but a 'cataract' or 'rapid'. The water comes splashing down a series of steps, sometimes going up-hill for a short distance as its force carries it over an extra big boulder. The water is travelling so fast here that it runs away more quickly than it is supplied and so it is shallow. The rocks on its bed disturb its flow, and it bubbles and 'boils' through the rapid with a very uneven surface, disturbing the air above it.

We hear the air-disturbance as a noise, for whenever shallow water flows swiftly over a rocky or stony bed it becomes noisy. This is true even when the disturbances are not grand enough to be called a rapid. In a great cataract, indeed, the water may roar like thunder, but many small streams provide miniature examples and Tennyson faithfully records their song:

I chatter over stony ways,
In little sharps and trebles,
I bubble into eddying bays,
I babble on the pebbles.

At the end of a swift passage the bed becomes comparatively level again and the stream slows down. The water is now arriving more quickly than it can flow away and so it accumulates and becomes deep once more. Here the surface is smooth because the stones on its bed are too far down to interfere with it. Although still moving onwards it may appear to be very nearly still, and Shakespeare's Duke of Suffolk (in *Henry VI*, Part 2) spoke truly when he said

Smooth runs the water where the brook is deep.

Now let us suppose that our river, instead of flowing over hard rock on to softer rock, flows down a valley it has cut in soft rock and then finds its way blocked by a barrier of much harder material. If it cannot wear a way through it, its waters will be dammed back and it will overflow its banks, flood its valley and form a lake. Presently the water will rise high enough to overflow the dam and there will be another waterfall—or perhaps a rapid, but the waters of the lake itself will be still and drop the load that the river was bringing down from the mountains.

Most of the load is dropped at the head of the lake, where the stream from the mountain enters it and is suddenly checked. Thus, whenever a lake is formed by the damming of a river, it starts to fill itself up with mud and gravel. The level of its bottom rises, and presently the lake has become dry land again, with the river flowing across it as before, but at a higher level. Every lake you see in the landscape is thus doomed to disappear long before the river (or rivers) flowing into and out of it. That is to say, it may last only ten thousand years or so!

The disappearance of a lake is often greatly helped by the headward erosion that goes on where the water overflows at the lower end. The waterfall here may cut back upstream like other waterfalls, and so the lake may be shortened at both ends simultaneously. Many bowl-shaped valleys nestling among the mountains and now supporting rich farms were once lakes that have got filled up in this way, and when one is only *half* filled up, you can see quite clearly what is happening by the marshes and mud-flats that are accumulating at its upper end. See Fig. 21.

The dam which causes a lake to form is not always

of hard rock. Sometimes it is a low hill of stiff clay, such as may be left behind by an old glacier after the ice has melted, and sometimes it begins as a pile of old tree-trunks and branches brought down by the river itself. These may get wedged across the stream, and then dead leaves, stones and mud pack into the tangle and make a watertight dam. In countries like Canada, artificial dams of this sort are built by beavers.

21. A scene in the English Lake District. The river drops its load of sand and mud on being brought to a stop by the still waters of Lake Derwentwater. The land is slowly filling up the lake.

They may be three hundred feet long and sometimes result in huge lakes. As these fill themselves in they get choked with vegetation and form 'beaver meadows'.

All these adventures belong to the valley tracts of rivers, where erosion and deposition go on at various places at the same time. In countries where the land slopes very gently down to the sea the rivers go through a third stage. When they reach the coastal area, which may be many miles wide and show hardly any slope, the rivers move very slowly

indeed. Water flows downhill but it stands still on a level surface, and here the ground is practically a flat plain.

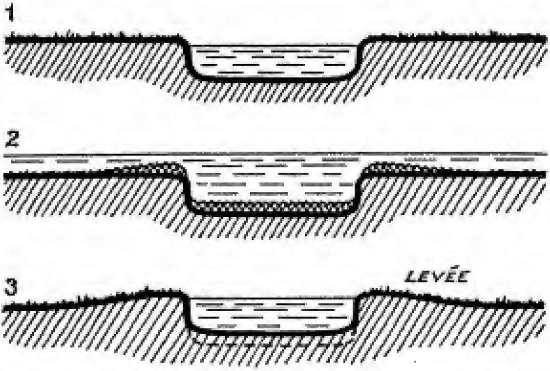
This is the 'plain tract' of the river, and quite often it has made the plain itself by widening its valley to such an extent that one side cannot even be seen from the other. It now does no down-cutting at all, and is simply engaged in depositing all that is left of its load, which by this time is chiefly mud. Just as there was erosion but no deposition in the torrent tract, here there is deposition but no erosion. The windings about that appear to involve erosion really do no more than rearrange the material that has been deposited.

Several new things happen in these circumstances. To start with, the river sometimes blocks up its own channel with mud, and then overflows and creeps round some other way. It may thus get divided into several streams which wander off across the plain and may later come together again, enclosing river-islands. When these are little more than mud-banks or gravel-banks, small compared with the river which divides and flows round them, they may be called 'aits', or 'eyots'. All the various branches of the river meander about to an extraordinary extent, trying to find lower levels, but even their banks are so low that they easily overflow and flood the surrounding ground.

When they do overflow, the water spreads out to form a still sheet across which the river can be seen slowly moving along its old course, scarcely disturbing the water on either side of it. But now it drops some of its mud on top of its own banks, so that when the floods subside the banks are found to be higher than they were before. The river continues to drop

mud on its bottom as well, and so it actually raises itself above the level of the surrounding land. The raised banks are called 'levees' and they are often artificially strengthened to check future floods. See Fig. 22.

Eventually, the river gets right down to the sea, into which it empties itself by its 'mouth'. When the tide



22. Another act in three scenes. Scene 1 shows a section across a river near its mouth. In Scene 2 it has overflowed and deposited mud on its banks as well as on its bed. In Scene 3 the floods have subsided, leaving the river bed and its banks raised a little higher than they were originally.

rises the sea-water may flow for some distance up the river-mouth, not only stopping the river but making it flow backwards perhaps for several miles. The mud deposited in the river's mouth thus gets washed to and fro' and sometimes piles up to form an island. The mud may also form an island when a river enters a tideless sea or a lake, if there are no currents to carry it away as fast as it is brought down. The river then

has two mouths, one round each side of the island. This is called a 'delta', from the Greek letter for D, which is written Δ. In some deltas, like those of the Nile and Ganges, there may be scores of mud islands and the river may have scores of separate mouths.

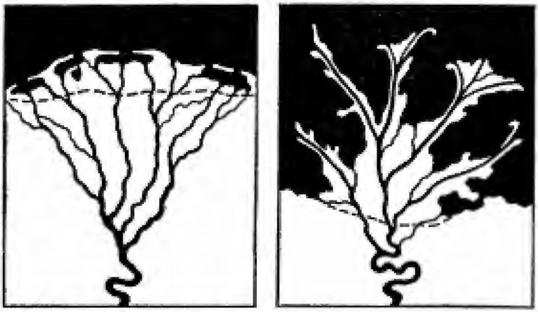
The battle between the river and the sea is not always won by the sea. The mighty Amazon, for example, invades the ocean with deep fresh water for a distance of three hundred miles. Sailors have crossed the Atlantic and died of thirst while still out of sight of land, though—had they but known it—they could have obtained all the fresh water they needed by simply lowering a bucket over the side of the ship.

A large muddy river like the Mississippi is able to turn the tables in another way, and build up its delta on the sea-floor instead of upon its own bed. This sort of delta has a distinctive form and may extend off-shore for several miles. The Mississippi brings down more than 800 million tons of mud every year and has, in fact, added more than 60 miles of new land to the coast. In one place it is pushing the coastline out into the Gulf of Mexico at the rate of 250 feet per year! The two kinds of delta are shown in Fig. 23.

Smaller rivers often contrive to drop their final load in the sea just opposite their mouths, and so build up a 'river bar'. Many rivers are partly closed by such bars, which may be visible at low tide but covered at high tide. If there is a port on such a river, a channel for shipping can be kept clear only by constant dredging. Submerged mud-banks or sand-banks of this kind may be added to by the sea itself in ways to be told in Chapter 5.

This concludes the eventful tale of a river, but when you look at a real river-valley you may sometimes

see signs of serious interference with the story. The fact is, the life of a river may be so long—perhaps a million years—that at various periods the land itself may have risen or sunk through movements of the earth's crust. Half-way through the story, for example, the mountains where the river rises may have been elevated, making the river flow more rapidly.



23. Two maps showing different kinds of river deltas. In your atlas you will see that the Nile has a delta of one kind and the Mississippi one of the other. The broken lines show the positions of the original coasts, so that you can see how much new land has been added by the river-mud. Most of the delta on the left lies in the basin of the river, but that on the right has been deposited almost entirely in the sea.

The effects of this are often quite easily seen, for the increased speed causes the river to begin down-cutting again in valleys which it had already begun to fill up with gravel, and so you can see a new valley appearing in the middle of an old one. This is illustrated in Fig. 24, where the level of the old valley shows up as a 'river terrace'. Many rivers show several such terraces, rising like steps along the sides

of their valleys, and it is always interesting to look for 'shelves' of this kind along a valley.

This renewal of a river's activities is called 'rejuvenation', which means 'making young again', and it may be especially easy to see its effects where the river meanders. You will remember that a normal meander shows one steep bank, or bluff, on the outside of the curve, and a slip-off slope on the inner side,

24. A river scene that tells a story. Raised above the present flood-plain you can see the two terraces that once formed part of its old flood-plain when it was at a higher level.

but some meanders appear to have steep banks on both sides. What has generally happened in such cases is that the river has been rejuvenated after the meanders were formed, and has started vigorous down-cutting in the old meanders. They are now called 'entrenched meanders', which explains them very well.

The effects on the mouths of rivers of the raising or sinking of the coast will be described in Chapter 5, and what happens when a river takes it into its head to burrow underground will be found in Chapter 4. But all the adventures in this chapter—and in those—may be seen quite easily at places where they are happening, and such places are as common as rivers

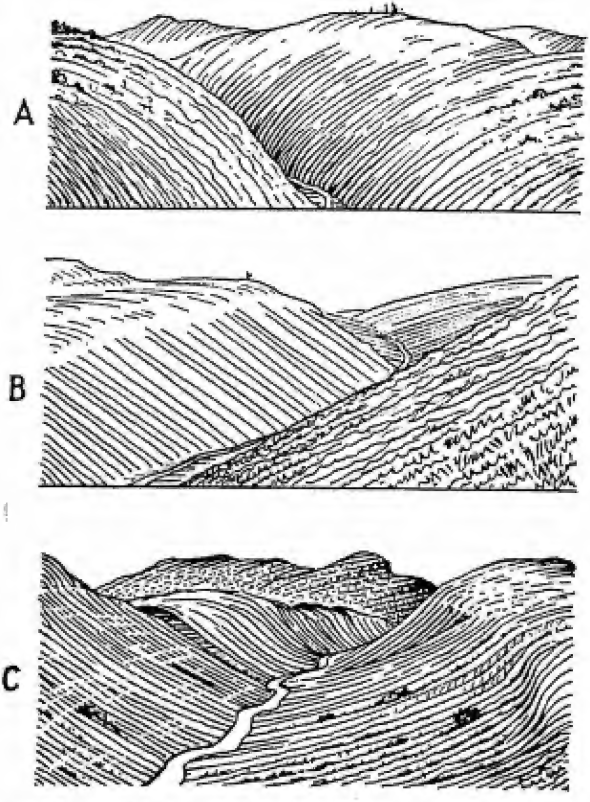
are. You have only to keep your eyes open when looking at any kind of river scenery, and you will be surprised at the number of tell-tale signs you can recognize at a glance, even in little streams and runnels.

3

Shaping the Mountains

No two mountains are exactly alike, though there are several distinct *types* of mountain. There are mountains with flat tops, mountains with sharp peaks, mountains with 'convex' slopes (which bulge outwards) and mountains with 'concave' slopes (which curve inwards). The form of their summits depends upon the weather and the nature of their rocks, but their slopes are really the slopes of the valleys which separate them and depend upon work done by rivers.

A river which cuts downwards faster and faster, perhaps because the rocks are softer down below, will produce a convex slope like that shown in Fig. 25 A. A river which cuts down at a perfectly even rate will produce a straight slope, as at B; and one that starts down-cutting rapidly, but finds it more and more difficult the deeper it gets, will produce a hollow or concave slope, as at C. But no matter what kind of slope a river produces at first, as soon as it begins to widen its valley it often makes the lower parts of the slopes steeper than they would otherwise be, and so the valley-sides may be like a wave—concave at one level but convex at another. Again, if the river has been rejuvenated there may be terraces along the slopes, and it is clear that almost every kind of form



25. Three valley scenes. The slopes are convex in A, straight in B, concave in C.

imaginable may appear on one mountain slope or another.

When you stand still and look at a mountain you can see the slopes of only two of its sides. It is usually difficult to make out exactly how it slopes towards you, and of course you cannot see what lies behind,

but the slopes of the valleys to the left and right are plain enough. Very often they are of different kinds, giving the mountain a lop-sided look, for the river which produced one valley may have been larger or swifter than that which produced the other. These are all things to *notice*, but when you have noticed them you can try to think out reasons for them. If you can find good reasons for about half of what you observe, you will have done very well.

In most mountainous regions, where there are scores or hundreds of peaks, the valleys have almost certainly been cut in a plateau, and one interesting thing to look for is some sign of the original high table-land out of which the mountains have been carved. To do this, you must start to climb one of the mountains, but often enough you can take some road that goes through a high pass for the greater part of your journey. After that, keep to well-marked foot-paths—for there are dangers to be met with on some mountains and the footpaths will not only avoid them but also provide the easiest way to the top.

When you get half-way up the mountain, stop and take a look round. You may seem to be hemmed in by other mountains, but between them you catch glimpses of more distant peaks. When you get a little higher you will be able to see over the tops of the lower heights, but only to find other ranges behind them. When you are really high up you will see further ranges behind these, and as you climb,

*Hills peep o'er hills, and Alps on Alps arise!**

Your general impression will be a great opening-up

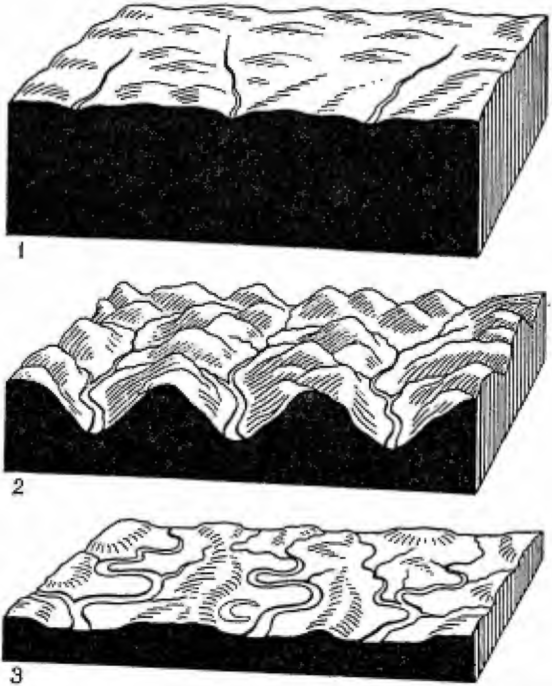
* Alexander Pope, *Essay on Criticism.*

of the country. At first, you were hemmed in by walls and could see only a few miles. Now you are on top of the world and can very likely see sixty or a hundred miles. The change of view was fairly sudden, and if you glance round you will see why. Although some of the mountains are not as high as others, most of the really big ones are all of roughly the same height. Their peaks are probably not far below the level of the original plateau from which they were all carved out, so that the broad view that you are looking at may be seen as a cut-up or 'dissected' plateau.

Of course, as the mountains get older they get worn down by the weather, but they all get worn down together. Unlike human beings, mountains grow shorter as they get older. It is the big, sharp-pointed, high mountains that are the young ones, and if you find summits smooth and rounded, like so many pillows, they are probably those of very old mountains indeed.

In the end they may be reduced to mere hills, and the rivers which carved the valleys between them now seem to be much farther apart. The hill-tops are no longer rounded but are worn flat and form a sort of level plain, but since this is still raised above the valleys we cannot call it a 'plain'. It is called a 'peneplain', which means 'almost a plain'. See Fig. 26.

That is really the life-story of a landscape. It began as a high plateau, was next carved up into mountains, and finally the mountains were worn down to mere stumps. The landscape was flat when it began, and it has become flat again at the end, so that the tale goes round in a circle. The changes were all brought about by erosion (by rivers and the weather), so that



26. An act in three scenes, entitled 'The Cycle of Erosion'. Scene 1 shows a plateau with three rivers. In Scene 2 the rivers have 'dissected' the plateau into a group of mountains. In Scene 3 the rivers, now very old, have carried away most of the rock and broadened their valleys by winding about, so that the land is once more nearly flat. Note the ox-bow lake.

this story is sometimes called the 'cycle of erosion'. Of course, the landscape takes a very long time indeed to run through its own tale. At least a million years are generally required, depending on how high the plateau was to start with, how hard the rocks are, and the climate of the country.

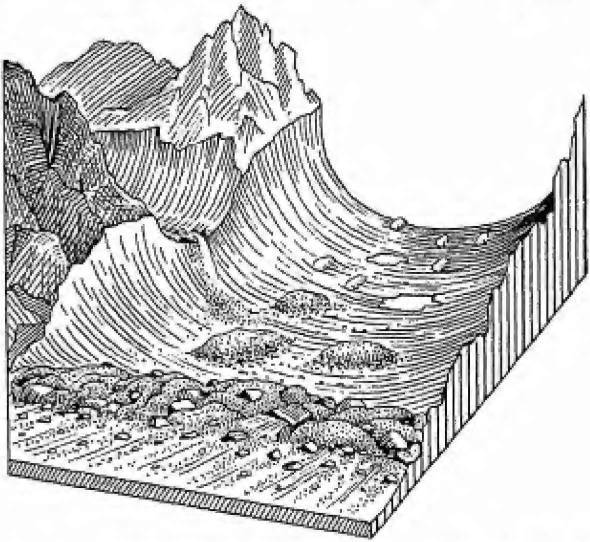
Before we broke off to outline this story, you had just climbed a high mountain and were admiring the view. Now take another look at it, but this time fix your attention on the larger valleys. Disregarding details, you may find that the bottoms of many of them are not even roughly V-shaped, like typical river-valleys, but U-shaped, with steep side-walls. Such valleys are very common in the northern lands, for they were not made by rivers of water but by rivers of ice, during the Great Ice Age. Such rivers of ice are called 'glaciers', and many of them were carving out these valleys only a few tens of thousands of years ago. See Fig. 27.

At that time it was so cold that the snow which fell never melted, but collected until it was enormously thick. It would have been many thousands of feet thick if its sheer weight had not squeezed its lower layers tightly together, changing them into hard ice. You will know how this happened if you have ever squeezed a snowball hard enough in your hand. So the country was covered with an ice-sheet, and frozen into the bottom of it were all the loose rocks, boulders and stones that lay on the surface of the ground.

Wherever the land was on a slope the ice started to slide down it. It moved very slowly, so that there was ample time for more snow to fall on the higher land and keep up a continual supply. During the Ice Age there were thousands of such sliding rivers of ice all over the northern lands, and they lasted for more than a million years. In fact, some of them are still there—in Alaska, North Canada and Greenland.

While the ice was moving it dragged along with it all the rocks frozen into its lower surface, and these were the tools which carved the deep U-shaped

valleys. The ice itself was several hundred—sometimes more than a thousand—feet thick and weighed millions upon millions of tons, and this alone would carve a valley (faster than moving water does), but just imagine the work it must have accomplished



27. This large piece of 'stage property' represents an old glacier-valley from which all the ice has disappeared. It shows a hanging valley, drumlins, kettle-holes, roches moutonnées *and a moraine. The text describes how it was carved.*

armed with rock-chisels and stone picks, which it dragged over the ground with irresistible force!

The ice cut both faster and deeper than water, and the glaciers often occupied old river-valleys, making them suddenly very much deeper. You can often see very clearly where this has happened, for the gentle slopes of the old, wide river-valley may still exist

above the steep sides of the glacier-valley. See Fig. 28. The smaller valleys of the side-streams that formerly flowed into the river are cut off short and can be seen high up on the sides of the glacier-valley. They are called 'hanging valleys', and streams may still flow down them to plunge over the edge as waterfalls. You may see one in Fig. 27.

28. The Pass of Llanberis, a glacier-valley in Wales. High up on each side you can see the gentle slopes of an old V-shaped river-valley. The glacier cut its deep U-shaped valley down the centre of this. A new river now flows along the bottom.

Now let us go down and look at the floor of the glacier-valley. If there is any bare rock here, one of the first things we shall notice is that it has been worn smooth and polished, but at the same time is scratched and grooved in nearly parallel lines. It is as if you scratched lines in the top of a polished table, or dragged a gritty polishing-cloth along it from one end to the other. These are the marks left by the ice, and it was by making maps showing their directions in all parts of the country that the movements of the ice during the Ice Age were discovered.

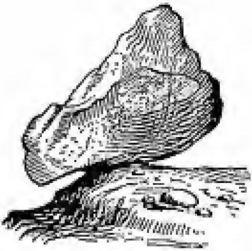
Here and there are rounded humps of rock, looking from a distance like the backs of resting sheep. They

are, in fact, called *roches moutonnées* ('sheep-rocks') and are the extra hard lumps that the ice was unable to wear completely away as it passed over them. There are also a great number of loose boulders lying about. Some may have tumbled in from the sides of the valley quite recently, but others did so while the glacier was still there and lay on top of the ice until it finally melted. They are worth looking at, for you can often tell what must have happened by simply seeing the kind of rock they are made of.

You see, rocks that have been resting on the glacier must have been carried along with it, and by the time the ice melted they could have travelled tens—or even hundreds—of miles. It is not uncommon to find boulders of granite or some such rock in a valley carved in slate or limestone. They must have been transported there by the glacier, and very likely the mountain from which they came can be found farther up the valley. In Britain, boulders have been found which must have come all the way from Norway on the ice.

Such odd rocks are called 'erratic blocks', and occasionally the ice has left them nicely balanced on top of a *roche moutonnée* or other such support, where they may rock to and fro when they are pushed. They may then be called 'perched blocks' or—if they rock—'rocking-stones'. See Fig. 29. Rocking-stones may, however, be produced in other ways, as we shall see.

If you are fortunate enough to see a real glacier, like that shown in Fig. 30, you will notice the long rows of stones and boulders that have fallen on to the ice from the mountains along both sides. They are now travelling slowly down the valley, generally at a rate



29. A perched block in the Pass of Llanberis, Wales.

of a few feet per day, although in Greenland there are glaciers which move as fast as sixty feet per day. There may be one or more rows of stones along the middle of the ice, too, and these indicate that the glacier must have been met by others farther up the

30. An Alpine glacier scene, showing the moraines, crevasses and seracs described in the text.

valley. When two glaciers meet, their side-rows come together and continue their journey as a single row, which is now in the middle of the combined glacier. These rows of stones are known as 'moraines'—'lateral' moraines at the sides and 'medial' moraines in the centre.

If the ground beneath the glacier is uneven, every time the ice passes over a rise deep cracks appear across it. These are called 'crevasses' and they can be very dangerous to travellers crossing the glacier, because they are sometimes hidden by snow bridges. When the ice passes over a hollow the crevasses may close again, crushing anything that may have fallen into them. Most of the crevasses run across the glacier, but they are not exactly at right-angles to it. They point slightly down the valley, and this shows that the ice in the middle is travelling a little faster than that at the sides. If they are crossed by other crevasses, running lengthwise with the glacier, the ice will be cut up into a field of jagged ice-pinnacles called 'seracs'.

In carving out its valley and polishing and scoring the rocks on the bottom, a glacier grinds enormous quantities of rock to a fine powder, which mixes with the water to form a thick, sticky clay. When the glacier has descended to a warmer level the ice melts and flows off as a river, but the clay and boulders it has brought down are dumped in a huge mound known as the 'terminal moraine'. The mixture of clay and boulders is called 'till', or 'boulder-clay', and today it may form a dam across the mouth of an old glacier-valley and cause a lake to form behind it.

Regions which were once covered by ice but are now free are often buried to a depth of several feet

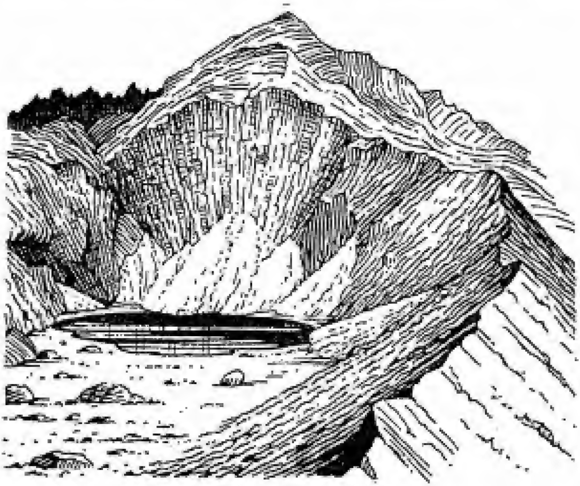
by the boulder-clay left behind as the ice retreated. This provides the northern countries with thousands of square miles of a special kind of scenery. The general appearance of a landscape which has been scoured by glaciers is a sort of wide hollow littered with rounded boulders, innumerable hillocks (called 'drumlins') and small hollows filled with water (called 'kettle-holes'). The scattered *roches moutonnées* look as much like gigantic eggs as sheep, so that this sort of lumpy landscape is sometimes called the 'basket-of-eggs' type of scenery. All these details are shown in Fig. 27.

Let us now walk right back to the head of an old glacier-valley and see where it started. Rivers start as springs, but glaciers as great masses of snow and ice too heavy to stay in place on the slope. In breaking away the ice pulls out a lot of the mountainside with it and leaves a great hollow behind. Now that the ice has gone we can see this hollow clearly. It looks like the back of a huge armchair, perhaps a thousand or more feet high, and there is probably a small lake where the seat ought to be. Such hollow backs are called 'corries', 'cirques' or 'cwms' (pronounced 'cooms'), and the lakes—which may be very deep—are called 'tarns'. See Fig. 31.

You can imagine the change made in the shape of a mountain by having a huge armchair scooped out of one side of it, and it often happens that two or three armchairs have been scooped out of the same mountain on different sides. What is left in the middle is a sharp-pointed peak, and when this makes a perfect pyramid it is often called a 'sugar-loaf' mountain. If two adjacent corries feed glaciers that run side by side, the steep walls of their valleys may cause a sharp

ridge to run out from the peak. It may be so sharp that only a practised mountaineer can walk along it, and it is called an 'arête'. One is shown in Fig. 31.

The face of a corrie, or that of an arête, is much too difficult for us to climb. This is not only because it



31. Scene at the head of an old glacier-valley showing the corrie and tarn, with screes of loose rock falling into the tarn. Also shown are a sugar-loaf peak, an arête and some aiguilles (in the background on the left). These features are described in the text.

becomes so steep towards the top, but because the lower slopes are littered with loose fragments of rock, like broken tiles. As soon as you start to climb on them they slide down, carrying you with them. They may form enormous piles which are called 'screes', and they have been made by another of our 'workmen'—Frost.

They may be found round any bare rock where it is exposed to the weather, but they come chiefly from the higher crags. At the foot of every rock-cliff there is usually a scree of fragments that have fallen from it. The breaking up of hard rock by frost is very important, for it is the chief source from which the mountain torrents get the stones with which they wear away their beds. In fact, every exposed mountain-peak is a sort of tool-factory, supplying the rivers and glaciers with their grinding materials and cutting tools. Let us see exactly what happens.

You know that you must not put a hot plate or a glass into very cold water (or a cold glass into boiling water), because if you do so it will probably crack. Now, on the tops of mountains the sun can be very hot indeed, but at night time the temperature may fall far below freezing. This is true even in tropical countries, if the mountains are high enough, and especially in desert regions where the ground is not protected by any clothing of vegetation. So the rocks crack, and in the course of years they become riddled with a whole network of cracks. This is the combined work of both sun and frost.

The cracks may be too fine to see, just as a crack in a plate may not show until it gets stained with gravy, but when the rain or dew falls it soaks down into all the cracks and fills them with water. At night time the water freezes. It freezes first on and near the surface, so that the top few inches of a crack may be completely sealed up and cemented together by ice. As the cold penetrates deeper the water lower down turns to ice also, and this is when the damage is done.

Water is a strange substance, for although most things expand when they are warmed and shrink

when they are chilled, chilled water begins to expand again just before it freezes into ice. It swells, and because it is sealed into the crack it forces the sides apart. It may do this with a force of a ton per square inch, widening the crack a fraction of a thousandth of an inch each time it happens. Presently, a piece of the rock—called a 'talus'—breaks right off and goes clattering down the mountainside to join the scree at the bottom.

This goes on every night on every high mountain-top, and during the winter in rocks exposed lower down the valleys, so that frost is one of the most persistent and hard-working of all the landscape-carvers. Round the world, many millions of tons of rock are being shattered and broken off by frost every night, and this goes on without ceasing for millions of years on end.

Most of the broken pieces get cleared away, sooner or later, by rivers, but the rocks from which they come show only too plainly how roughly they have been treated. The top of a mountain of hard rock often looks as if it had been hacked about with a giant chopper, showing jagged spikes and *aiguilles* (needles) of the most fantastic shapes. Those illustrated in Fig. 31 have been taken from an actual example in the Alps.

So far, we have described the mountain-shapes due to carving by rivers, ice and frost, but other well-marked shapes may be caused by the arrangement of the rock-strata of which a mountain is built. Shapes of this kind may be evident even in hills clothed with grass or woodland and not showing any bare rock at all.

In Chapter 1 we read how the vast layers of rock

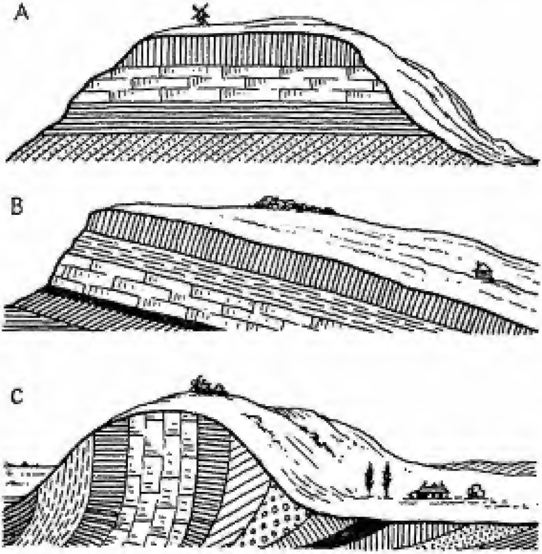
composing most of the land of the world have been bent or folded in every imaginable way, and it is natural that in some localities their arrangement should show on the surface. It often shows indirectly, for though the landscape may have been carved entirely by rivers, it is likely enough that the rivers were guided by the rock-formations beneath them.

In Fig. 4 (page 19) we illustrated how beds of soft rock are liable to get worn away more quickly than beds of hard rock, and it is easy to see how a map of the hard and soft rocks on the ground provides a plan for the rivers to follow. It often works out this way, but the rivers do not always follow the plan provided for them. A swift river on a steep slope runs straight downhill, cutting across hard and soft rocks alike, and when it gets older and flows more gently it usually keeps on in its old course.

Evidently, we should not pay too much attention to the underlying rocks (unless we are studying geology and know how to find out about them), but there are three outstanding cases which we can often recognize without any difficulty. They not only provide mountains of special shapes, but they are also generally accompanied by the arrangement of rivers we should expect. They are shown in Fig. 32, but you must picture these diagrams on a big scale, for each may represent many miles of country.

In the first case, at A, the beds of rock are horizontal and form a small plateau. Though you cannot be sure that *every* flat-topped hill has a flat bed of rock on the top, it is likely enough to be so if the hill is a small one and has steep sides. In this case it is called a 'tabular' hill—a hill like a table. In America such a hill is often called a 'mesa' or, if it is very small, a 'butte'.

When the flat beds on a tabular hill or a plateau consist of alternate layers of hard and soft sandstone, the rain and wind may lower the surface fairly rapidly. Any hard patches are then liable to stand up on it as knobs of a curious shape. This is shown in



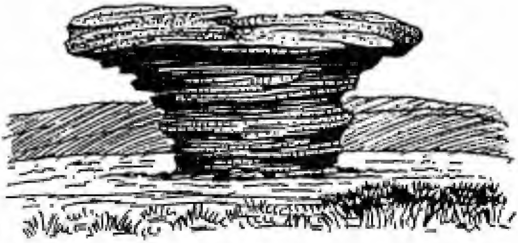
32. The horizontal beds at A form a tabular hill, the sloping beds at B an escarpment, and the vertical beds at C a hog's-back.

Fig. 33, and the undercutting which provides the knob with a 'stalk' is done by the wind.

As you can imagine, a good deal of loose sand may lie about on the top of such a plateau, and when the wind blows it raises the dust and sand and carries it along. As it blows against the projecting knobs of harder rock it wears them away like a mason's sand-

blast, but the heavier sand-grains do not rise very high so that most of the blasting is done round the foot of the knob. It may cut right through the base, leaving the knob precariously balanced as another kind of rocking-stone. Unlike the rocking-stones found in glacier-valleys, this kind is always made of the same kind of rock as that on which it rests.

In shape, these knobs of sandstone may remind you of toadstools or umbrellas and, like umbrellas, they



33. A 'mushroom' rock carved by blown sand. This is an example of the work done by wind.

help to protect the ground beneath them from rain. The patch of rock on which they stand may thus show less signs of weathering than the surrounding surface and appear raised up as a kind of 'boss'. This sort of umbrella protection is not peculiar to sandstone knobs on tabular hills, and in other circumstances it may produce different—but equally odd—effects.

In the valleys of the Alps, for example, the blocks in the boulder-clay sometimes cap tall columns of stiff clay, the unprotected clay around having been all washed away. These are called 'earth-pillars' and are illustrated in Fig. 34. Earth-pillars may also occur in

warmer climates where there is deep soil and heavy rain, and you may sometimes find minute examples in your garden (though they soon fall over!).

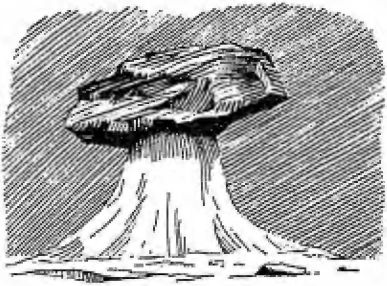
Near the mouths (or 'snouts', as they are called) of glaciers, where the ice is beginning to melt, the

34. Earth-pillars in France, each with its little cap or umbrella of rock.

boulders of the moraines may act as sunshades. They prevent the ice beneath them from melting though it may be disappearing rapidly all round. As the ice around vanishes it leaves the boulders supported on short pillars, making what are called 'glacier-tables', or 'ice-tables'. See Fig. 35.

In deserts where the strata lie horizontally a kind of

pillar may appear in which the rocks on top do not act as either sunshades or umbrellas. Exposure to the hot sun during the day, followed by the cold nights, causes the beds of rock to crack, so that the entire desert may be criss-crossed by deep fissures. But these get widened by sand-blasting so that only the hardest rocks are left standing like pillars between them. The



35. An ice-table on a glacier.

heat of the sun goes on cracking the rock, but chiefly on the exposed tops of the pillars, so that they become narrower and sharper until they presently look like a forest of church spires. But we must pass on to our other two outstanding arrangements of strata.

The second special arrangement of rocks is shown in Fig. 32B, and in this the beds are tilted at an angle so as to form a sort of cliff. The rivers here are likely to flow down the gradual slope, but also along the foot of the cliff (at right-angles to the page). The gradual slope is called the 'dip slope', because the beds of rock dip in that direction, but the cliff is called a 'scarp' or 'escarpment'. If you look back at Fig. 4 (page 19) you will see that a simple fold of rocks may,

when the top has been removed, provide two whole sets of escarpments facing each other. There is a distant view of an escarpment in the background of Fig. 16.

The third special arrangement is shown in Fig. 32C, where the beds of rock stand up vertically. If they are fairly hard they will make a long, narrow ridge of hills with sides of equal steepness, and this is called a 'hog's-back'. The rivers will flow parallel with it on both sides and it is, of course, their valleys which show it up.

We have only one other kind of hill or mountain to describe, and this is the volcano—or the remains of one that has been weathered away. A complete volcano was illustrated in Fig. 10 (page 27), where it clearly makes a perfect cone with a hollow crater in the top. In countries where there are now no volcanoes we do sometimes come across the relics of old ones, but all that usually remains is the column of hard igneous rock in the very centre. It is called a 'volcanic neck' and is generally worn down to a rounded stump with very steep sides.

Edinburgh Castle, in Scotland, is built on top of a volcanic neck, and another example is shown in Fig. 36. Volcanic necks are nearly always made of basalt, but when larger masses of igneous rocks, formed deeper underground, become exposed by the weather in the same way they are often of granite. These form the 'knobbly' kinds of mountain described in Chapter 1 and illustrated in Fig. 11 (page 29), but they may also form extensive tracts of moorland rising to peaks here and there.

At such peaks the bare rock may be seen, but it is generally cracked and jointed in a peculiar manner

36. A church built on a volcanic neck at Le Puy, France. There are steps to the top.

37. Bowerman's Nose, a granite tor on Dartmoor, England.

which suggests giant masonry. The cracks in granite tend to form at right-angles to each other and so make roughly square blocks. Piles of these blocks mark the high-points of the moor and are called 'tors'. See Fig. 37.

The effects of the sun and the weather have generally rounded off the corners and edges of these blocks, and it occasionally happens that *all* the projecting angles get flaked off so as to reduce the block to the shape of a giant cannon-ball. Such a block protects the ground immediately beneath it and so appears perched on a short base, or plinth. If it rocks when pushed it makes yet a third kind of rocking-stone. Here again, both the boulder and its plinth are made of the same kind of rock, and this enables you to tell it from an erratic block carried into place by a glacier.

4

Aladdin's Cave

Let us take stock of the workmen we have so far been watching and make a list of their jobs. In Chapter 1 we named them Fire, Water, Ice, Frost, Snow, Sunshine and Wind, and we have now seen them all in action.

Fire places the igneous rocks in position and sometimes uses them as wedges to force dykes and sills between other rocks, as we showed in Fig. 10. Water uses stones to carve and widen river-valleys, employing them as hammers and abrasives, and is itself a sort of wheel-barrow to carry the rubbish away. Ice uses stones to carve valleys, too, but handles them rather as chisels and picks, and it finishes off its work as a polisher. It also performs prodigious feats as excavator, bulldozer and mineral tramway.

Frost drives wedges into the rocks and splits them asunder, making every rocky peak into a tool-factory. Snow, falling on the mountains, grips the tools firmly as it turns into ice, holding them as in a powerful vice. Sunshine works with Frost and Snow to crack the rocks, and Wind picks up dust and small fragments to use as a sand-blast for carving queer knobs and pillars.

The carving and shaping of the landscape has been

proceeding apace, but there is more yet to be done by Water. In this chapter we shall complete the tale of work accomplished by fresh water, and in the next tell the story of the sea.

The work of water so far described has been vigorous and mechanical, and we have been able to see much of what goes on, but water also does invisible work of which we can see only the results. This work is chemical, and depends upon the power of water to dissolve substances. Salt and sugar are the two most familiar substances that will make a solution in water, but every known solid dissolves to a greater or less degree. Even glass is slightly soluble, though the trace of glass which dissolves in your half-pint tumbler is far too minute to be detected.

The materials of which rocks are made are called minerals, and some dissolve in water more readily than others. With many, solution is greatly helped if the water has been exposed to the air, for it then contains carbon dioxide gas and is very slightly acid. The most common source of natural water over the land is the rain and this always contains *some* carbon dioxide, even if only a trace. It may take up more if it lies for some time on the ground, and it is really a kind of very weak, flat 'soda-water'.

Such ground-water is able to dissolve many common minerals. This is generally a very slow process, a lot of water being required to remove the tiniest quantity of mineral, but limestone dissolves comparatively easily. If the water-supply in your house has come from limestone hills there may be as much as half a dram of limestone dissolved in every gallon. As you boil the water away in your kettle the limestone is left behind on the bottom as 'fur'.

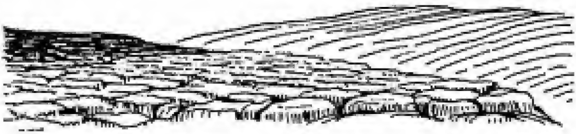
There is no need, of course, to *boil* the water away. If it is just left to evaporate, or 'dry up', it leaves its limestone behind as a kind of hard scum. In some country districts where the streams have been flowing over limestone you may find 'petrifying springs'. The people here will hang up small objects, such as birds' nests, so that the water trickles slowly over them, and after a time they become coated with limestone fur and appear to have been changed into stone. The word 'petrify' means to change into stone, though the objects are not really changed except in appearance.

The rocks over which the water flows also get coated with fur, especially underground where they are not liable to get washed with fresh rain. It happens wherever the water is moving so slowly that it partly dries up as it flows, and after many thousands of years a very thick deposit of fur may accumulate in this way. It is called 'tufa'. But before this can happen the water must have been travelling long enough over limestone rocks to contain enough in solution. Such water is said to be 'hard', water which contains no limestone being called 'soft'.

In many parts of the world, and in some parts of most countries, there are whole ranges of hills or mountains made entirely of limestone. Like most other rocks, limestone is full of cracks and joints and the rain falling on the hills soon finds them out. It trickles down them, dissolving some of the rock as it goes, and soon they become quite wide. The soil may now fall down the cracks and get washed away, leaving nothing but bare rock on the surface. Plants cannot grow on bare rock so the hill now appears to be covered with badly-cracked, rather lumpy paving-

stones. If it is like this over a wide area the desolate type of scenery produced is called a 'Karst' landscape, after the Karst plateau in Yugoslavia where there are hundreds of square miles of it. See Fig. 38.

The widened cracks in the limestone are called 'grikes' and the rough squares of rock between them 'clints'. The grikes may grow into large holes, leading down into the interior of the mountain.



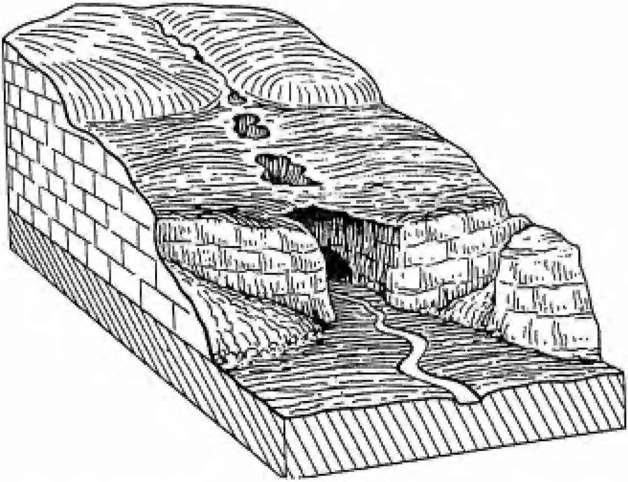
38. A wide pavement of limestone 'clints' on the Yorkshire Moors.

Similar holes are liable to occur on any limestone hills, whether turf is growing on them or not, and they are known as 'solution holes', 'sink holes', 'swallets' or 'swallow holes'. They can make a mountain really dangerous to travellers, for an unwary walker may suddenly find himself on the brink of a hole of unknown depth.

Swallow holes often form in the beds of rivers in limestone districts, and may swallow up some—if not all—of the water. Sometimes the rocks and pebbles on the bed of a stream conceal a whole series of small holes and cracks in the limestone underneath, causing the river to dwindle gradually away although the 'leaks' cannot be seen. A very great deal of water finds its way underground through such holes, as well as through grikes on the bare moors, and down below it may dissolve out quite large tunnels through

which it flows as an underground river. See Fig. 39.

Such rivers often travel for many miles through the heart of the mountains and then come out into the daylight again at a lower level. They may break out in a series of large, gushing springs or flow quietly out of a tunnel-mouth at the foot of a cliff. Like the rivers



39. This piece shows a river flowing over limestone country and disappearing down swallow-holes to become an underground stream.

above ground, they sometimes do an enormous amount of rock-carving. They cannot, of course, make wide valleys inside a mountain, but they do hollow out tremendous subterranean caves, far bigger than you might think possible. Many of the swallow holes on the mountains and moors are now little more than openings in the roofs of such caves.

A famous example in Britain is Gaping Ghyll on the slopes of Ingleborough, a mountain in the Pennine moors. The opening is neither very large nor easily seen (until you are close to it), but if you were lowered through it on a rope it would be necessary to pay out 365 feet before you found the bottom! Here, you would find yourself in a vast hall 480 feet long.

On the surface of a limestone plateau in Kentucky there are more than sixty thousand sink holes, leading to hundreds of caves. Among them, the great Mammoth Cave has more than thirty miles of passages. In the Carlsbad Cavern in New Mexico there is a 'Big Room' 4,000 feet long and 600 feet wide, with a ceiling which—at its highest point—is 300 feet above the floor.

The descent into such caves on a rope should never be attempted except by experienced climbers. Exploring underground caves can be very dangerous, though it is sometimes possible to find a safe way in through a tunnel-mouth or a wide cleft level with the floor of a cave. But it is never wise to enter *any* cave without taking proper precautions against accidents.

The most important requirement is a lamp, and if an electric torch is used spare bulbs and batteries should be carried to make sure of getting out again if the light fails. It is always foolhardy to take a step in the dark in a limestone cave, for the rocks are usually wet and slippery and there may be deep swallow holes in the floor. Even with a lamp, it is unwise to enter such a cave alone and nobody, whether accompanied or not, should start exploring without first telling somebody outside where they are going. Apart from other hazards, underground tunnels often form complicated labyrinths, or mazes, in which it is

much easier to get lost than to find the way out again.

But once we are inside we may, if we are lucky, find a kind of landscape—or rather, cavescape!—that could be represented in stage scenery only by an Aladdin's cave or a fairy grotto. The light from our torches is reflected back from a myriad sparkling crystals on the walls and roof, and the whole cave seems to be filled with a soft glow. Long, slender

40. A grotto scene. Stalactites and stalagmites in a limestone cave.

spikes like icicles hang from the roof and others stand up from the floor, while sheets and curtains of the same material hang across corners or drape the walls. Here and there, roof and floor are joined by slender pillars or clusters of pillars like organ-pipes, and all around the rocks are covered by what looks like icing-sugar. Fig. 40 shows a collection of these forms taken from some famous caves including the King's Chamber in the Carlsbad Cavern and the Jenolan Caves of New South Wales.

Let us examine these decorations more closely. They may be white, yellow, pink, pale blue or green, or rust-red, and glint and sparkle every time we move our lamp. If we hold the lamp behind one of them the light shines dimly through, as if through thin porcelain. They look soft and waxy, rather like coloured candle-grease, but they are cold and hard to the touch and covered with a film of moisture. If we strike one gently with a walking-stick it may ring like a bell. If it breaks off, the broken surface is rough and glittering and shows innumerable flat crystal-faces, set at all angles.

Now, it is hard to believe that all these beautiful ornaments are of the same substance as kettle-fur, yet the only real difference is that kettle-fur collects rapidly and these deposits form slowly. A new kettle may be lined with fur in a few weeks, but a cave may take twenty thousand years. The water in the kettle is boiled off quickly and the limestone is hurriedly thrown down as millions of tiny grains or crystals that are too small to be seen separately. But the water in the cave dries up so slowly that when the first minute crystals have been deposited, the next ones, instead of being hastily thrown down beside them, fit themselves on to the first set, face matching against face, and the result is not two sets of tiny crystals but one set of larger ones. And so the crystals go on growing until they are big enough to be seen, and masses of them are semi-transparent like barley-sugar.

We can compare the limestone deposited quickly in a kettle with a load of bricks tipped suddenly out of a cart. They just make an untidy heap. But the limestone deposited in the cave is like the bricks of a wall,

each one having been neatly laid in place so that its faces fit against those of its neighbours. It naturally takes much more time for this careful work to be accomplished, but the water trickling through a cave in the heart of a mountain has all the time in the world.

The stone 'icicles' hanging from the roof are called 'stalactites', from the Greek word for 'drip', and we can now picture how they get their shapes. A drop of water hanging from a low point on the roof of the cave may stay there for a while before it falls, and while it hangs it partly dries up and deposits a crystal of limestone. The next drop runs down to the same low point and adds its crystal to the first, and so the stalactite grows downwards as long as drops continue to fall. It may measure anything from a fraction of an inch to a few yards in length, according to its age and how fast it has been growing. A common rate of growth seems to be about a quarter of an inch in a hundred years, but some stalactites have not become noticeably longer since they were first measured more than a century ago. Some are as thin as pencil-lead while others are as big round as you are, but the big ones must be tens or even hundreds of thousands of years old.

The wavy stone 'curtains' that often hang from the roof of a cave are produced when the water comes through a crack instead of dropping from a point, and stone 'organ-pipes' may grow where it trickles out of cracks in the walls. But however it arrives it eventually finds its way to the floor of the cave, and here it deposits more of its limestone crystals. The drop that falls from the tip of a stalactite splashes on to the floor, where it dries slightly before it runs away

and leaves a minute crystal exactly beneath the stalactite. The next drop to fall lands on top if it (for there is no wind here to deflect it) and adds its own crystal, so that a sort of stone 'candle' begins to grow upwards. This is called a 'stalagmite', from the Greek word for 'drop', and it may presently grow so high that it meets the stalactite and forms a pillar.

As the water runs off the growing stalagmite it deposits more crystals round the side, so that stalagmites are generally fatter than stalactites. They look more like candles that have guttered and spilt their grease all round them. A deposit of stalagmite is often found to have spread all over the floor of the cave and it may be several feet thick. Such floors have sometimes been dug up and the bones of men and animals that lived in the caves thousands of years ago have been found preserved in them as in a marble tomb.

The delicate tints which colour the stalactites and stalagmites are caused by traces of metals in the limestone. The reddish-brown ones, for example, are stained by the rust of iron, the blue by lead and the green by copper. The merest traces of these metals are sufficient, but they show that the water bringing the limestone must also have travelled somewhere across rocks containing their ores.

All the ores of the metals dissolve in water, given enough time, and when the water contains nothing much else *but* the ore of a metal, it may deposit crystals of the pure ore instead of limestone. But the ores of metals are neither as plentiful nor as soluble as limestone, so that their crystals are rarer. They do not often line caves, but are more usually found in clusters

in cracks in the rocks, which they sometimes completely fill.

Water which has flowed over sandstone country, or over moors of igneous rocks, may likewise dissolve quartz or silica and later deposit it as 'rock-crystal' (which often looks like clear glass). But neither these crystals nor the metallic ores contribute anything much to the 'cavescape', except to provide a brighter sparkle here and there, and they do not really belong in this book.

There is, however, one other way in which ground-water may produce striking landscape features. This is when it goes down through cracks and crannies to depths where the rocks are hot enough to boil it. This naturally happens most frequently in countries where there are active volcanoes, but it also happens in places where there is no volcano within several thousand miles. The water may eventually come up again as a hot spring, and in some countries—such as Iceland—it may be led away through pipes for heating houses or public baths. But sometimes there is a much more exciting result.

When the water has reached a great depth it is under pressure from the weight of all the water in the crack above it. The deep water under pressure will not boil into steam until it has been heated above the ordinary boiling-point, but when it does begin to boil the steam blows upwards and some of the water is spilled out of the top of the crack.

The water at the bottom is now under less pressure than before, and so its boiling-point is not so high; it finds itself hotter than its new boiling-point, so it suddenly explodes into a huge volume of steam. This blows all the water out of the crack in a huge, scalding-

hot fountain called a 'geyser'. The fountain plays for a few minutes, until all the water has been blown out, and then there is a period of waiting while the crack fills up and boils again. See Fig. 41.

41. The Old Faithful geyser in eruption, Yellowstone National Park, U.S.A.

The waiting time varies for different geysers, but it is often very regular for a particular geyser. The Old Faithful, a geyser in the Yellowstone National Park,

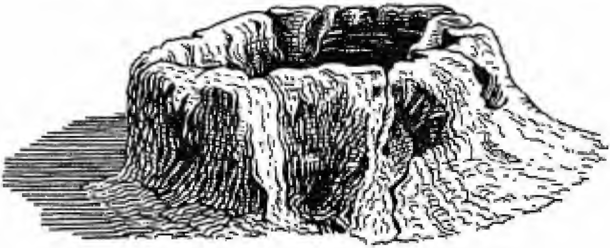
U.S.A., erupts regularly every sixty-five minutes, sending up a column of water six feet in diameter to a height of a hundred and fifty feet for exactly four minutes. Before it plays it gives a few deep growls by way of warning. It has been playing, night and day, for untold ages and keeps such good time that it has been called 'Eternity's Timepiece'.

There are many such geysers in Yellowstone Park, and the big ones have such picturesque names as the Giantess, the Beehive, and the Chinaman's Laundry Tub. Another great geyser country is the North Island of New Zealand, and a third—the only other with a really big geyser—is Iceland. The Great Geyser in Iceland, which is situated near the volcano Hekla, throws a column of water and steam to a height of nearly two hundred feet every twenty-four hours. Its Icelandic name, *Geysir*, gives us the word 'geyser'.

The hot water of a geyser naturally contains several minerals dissolved in it, and these are deposited as incrustations when the water evaporates. They form small mounds or rings of tufa round the mouth of the geyser, sometimes raising it to form a sort of squat chimney or funnel. These also may have queer local names, and one at Whakarewarewa, New Zealand, is known as the 'Brain Pot'. It is illustrated in Fig. 42.

Some of the New Zealand geysers contain dissolved silica, which is deposited as a very hard, glassy substance called 'sinter'. It is often beautifully coloured, and at Rotorua it once formed two magnificent sets of terraces, one white and one pink. They looked like petrified waterfalls descending in a series of broad, shallow steps, but they were destroyed when the volcano Tarawera erupted in 1886.

Nothing much can grow where the hot water of a geyser has been splashing, so that the scenery round about is often composed of bare rock on which the funnels and mounds of tufa stand, with small ponds of steaming water in all the hollows. There may also



42. The Brain Pot, the mouth of a geyser in North Island, New Zealand.

be some 'mud volcanoes', which are really geysers filled with mud—sometimes mixed with sulphur—instead of clear water. The mud does not flow away as easily as water, but collects to form a conical hill with a crater in the top, much like an ordinary volcano but seldom very large. Near the Russian town of Baku, on the Caspian Sea, there are mud volcanoes 250 feet high, but nothing worse than boiling-hot mud ever comes out of them.

We close this chapter with the old Song of the Mud Geyser:

I'm the Dragon's Mouth, the geyser—
Mother Earth, we do despise her.
Come not near me!
Can't you hear me?

E'en the beasts and wild birds fear me!
Down within me, hear me roaring,
Hear my tumult and my snoring.
Belching forth with mud and sulphur—
Mother Earth I would engulf her!

5

The Work of the Sea

We have seen fresh-water at work in a variety of ways. It has carried sand and stones along and used them as tools, it has sorted them out and built dams and banks by dumping them, it has washed away soil and dissolved rock. The sea does all these things, too, but adds the duties of a rake, broom, woodsman's axe, sledge-hammer, battering-ram, shrapnel-shell and hydraulic press.

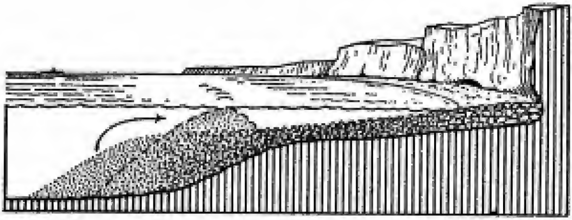
The tools that it uses are found lying on the beach, and they consist of loose stones and rock-fragments that have been weathered or knocked from the cliffs and fallen down. If the sea is in a gentle mood it starts work in 'that unaccountable way which the sea has always in calm weather, turning the pebbles over and over as if with a rake, to look for something, and then stopping a moment down at the bottom of the bank, and coming up again with a little run and clash, throwing a foot's depth of salt crystal in an instant between you and the round stone you were going to take in your hand; sighing, all the while, as if it would infinitely rather be doing something else'.

That pretty description—it is John Ruskin's—may remind you of many pleasant days spent on the sea-shore, when you have watched the sea doing its

raking without realizing what a lot of important work was really being accomplished. It is this work of 'raking' that we shall look at first, for so much of the coastal landscape depends upon it.

To start with, stones always roll down a slope if it is steep enough, and often get help if it is not. The sea provides help in two ways. If it covers a stone it buoys it up a little, relieving it of about one-third of its weight. Then, when the sea runs down the beach it gives the stone a gentle push, so that it rolls down with it. The sea can easily move a stone five inches in diameter over smooth sand, even when it is flowing at only two miles per hour.

It is naturally much harder to push the stone *up* the beach, so that on the whole the first result of the raking is to drag the beach slowly down and under the water. The beach does not disappear because it is always being renewed by fresh stones falling from the cliffs, but it gets broader and stretches out for some distance under the sea, where it forms a 'wave-built terrace'. This, and a few other details which we shall be noticing in a moment, is illustrated in Fig. 43.



43. A section across a beach showing the wave-built terrace. The arrow shows how the sea may pile some of the sand back on to the terrace to form an off-shore bar.

The edge of the terrace occurs where the water becomes too deep for the waves on top to shift the sand or stones any farther. As more arrive they just tumble over the edge, forming a steep slope. The angle of this slope never varies for long, for if it gets too steep the top slides down, just as the sides of a sand-castle will if they are piled up too high. Big waves during the next storm will sweep up what has fallen and pile it back on top again. They sometimes pile up enough to make a large sand-bank on top of the terrace. This is called an 'off-shore bar', and boats can run aground on it if they are not careful. An off-shore bar is shown by a dotted line in Fig. 43.

Now, in doing its raking the sea causes the pebbles to rub and bump against each other, so that they first lose all their sharp corners and then get nicely rounded. The grains that are knocked off them form sand, which drops down between them and provides a sandy bed to the beach. The whole of a beach may be ground down to sand in this way, especially if the cliffs behind are made of a soft sandstone rock.

The third thing the sea accomplishes by its raking is to sort out the grains by sizes. You will remember how a river drops its large stones first, but is able to carry its sand much farther and the mud farther still. Well, the same thing happens on the beach. The small pebbles get carried farther than the large ones, and the fine sand farther than the coarse sand. The finest grains of mud cannot settle down until they are in such deep water that there is practically no motion at all, even when a storm is raging overhead. This may be a very long way out indeed—far beyond the edge of the wave-built terrace.

All this happens whether the sea is calm or rough,

but when the waves are really big a great deal more happens as well. It is time we took a closer look at these waves. They have been rolling in on the shores of the world, without a moment's pause, for at least three thousand million years, and we may well ask what causes them. The answer is very simple: it is nothing but the wind. A sailor can guess the speed of the wind by merely glancing at the waves, and it is only when there is no breeze at all that the sea can be 'like a mill-pond'.

The seas are quiet, when the winds give o'er,

wrote Edmund Waller in the seventeenth century, and no doubt some of our Stone Age ancestors made the same observation several thousand years earlier, but it is only in quite recent times that the exact relation between the wind and the waves has become known. This, too, turns out to be very simple.

The farther the wind blows over the water, the bigger the waves it can raise, but it can never make waves higher than is given by this relation: *the height of the waves, in feet, is equal to half the speed of the wind, in miles per hour.* For example, if the wind is blowing at ten miles per hour, the waves can be five feet high but no higher. To whip the waves up to this height the wind might have to blow over the water for some miles, and the distance it has thus blown is called its 'fetch'.

Ten miles per hour is the speed at which the wind begins to break up the tops of the waves into flakes of froth, or 'spume'. These are sometimes called 'white horses', and another name is 'spindrift'. During storms in the open ocean, where the wind has an unlimited fetch, waves forty or perhaps even fifty feet

high have been met with (though their height is usually exaggerated). When these occur the wind must be blowing at eighty or a hundred miles per hour—a hurricane. The tops of the waves are then blown right off, clouding the atmosphere with a misty deluge of salt rain which is flung violently about by the storm.

Once the waves have been produced, it is a different matter altogether to quieten them down again. The wind may drop in half an hour, but it will take much longer for the sea to settle down. Thus, you may have waves for some time when there is no wind at all. Again, there may be no wind where you happen to be, but if there is a storm raging a few hundred miles out to sea, the waves it is making may come rolling in right to your feet. They cannot stop suddenly at the edge of the storm (if a storm can be said to *have* an edge!), but will travel outwards in all directions, dying away only very gradually. Waves that occur where there is no wind, from either of these causes, make what is known as a 'swell' or 'ground-swell'.

Let us get back to our beach and watch the waves come in. We now know what causes them, but we have not yet said what they *are*. Just what *is* a wave? It certainly looks like a heap of water travelling along, yet we know quite well that this cannot be true. Throw a cork into the sea—or a pond, for that matter. It merely bobs up and down as the waves pass beneath it, but if the water was actually travelling along it would carry the cork along with it. The fact is, the waves are not the water itself, but only its *shape*.

One of the best illustrations of how a wave travels is seen when a field of corn is ruffled by a puff of

wind. As the rows of corn-stalks bow their heads in turn, one after another, a ripple seems to travel across the field. It is not the corn that travels, but the line of bowing. It is the same with water. As a wave passes the only motion in the water is that it rises and sinks again, but as it sinks the water next to it rises, and when that water sinks the water next to that rises, and so it plays a sort of 'pass-it-on' game in which each particle of water bobs up and down as its turn comes.

This small motion of the water extends some short distance below the surface, for clearly the surface does not leave the top of the water when it rises! So a wave has a certain depth, and as it comes in to shallower water the lowest part of it presently reaches the bottom. Here, the sand or shingle hinders its movement and it is slowed down, but the top of the wave carries on at the same speed and so topples over. It is just as when you are running along and then trip over a stone. You will fall flat on your face, and so does the wave. It 'breaks'.

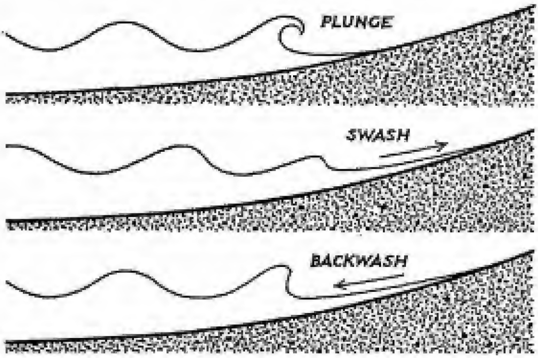
When this happens, the water in the top of the wave is thrown forward and falls bodily on to the beach, and it rushes up it by the sheer force of its fall. Then it runs down again, dragging the stones with it, to disappear beneath the next wave as that is about to break in its turn. The actual tumbling over of the wave is called its 'plunge', its rush up the beach is the 'swash', and the run down again is the 'backwash'. The distance the water runs up the beach is called its 'send', and all these terms are illustrated in Fig. 44.

The falling and splashing of the waves, and the raking of the stones by the water, make a pleasant, confused noise which poets never tire of trying to

describe. Homer wrote nearly three thousand years ago of

. . . *murmuring surges breaking on the shore**

and nobody has ever done better, for this sound is unlike anything else in nature and cannot really be expressed in words. Away from the sea, the sound most like it is the sighing of the wind in the trees



44. How a wave breaks on the beach. The distance the swash runs up the beach is called the 'send'.

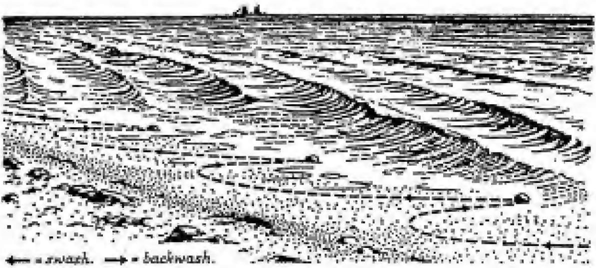
when the leaves are just dry enough to make a faint rattle, but the wind must be imagined to rise and fall as regularly as if it were breathing, its soft moan mingling with the rustle of the leaves to make a single sound. It is one of the great voices of the landscape, a subject we shall return to before we close this book.

We have more yet to say of the waves, and we must pause to look again at the manner in which they move the stones on the beach. Though the backwash may

* Alexander Pope's translation.

drag them down a long way, the swash of the next wave may send them up again, though for a shorter distance. Thus, their journey down to the sea is not a smooth one, but a zig-zag of repeated ups and downs, the 'downs' being always a little longer than the 'ups'.

You might not think this was a very important detail, but if you were a ratepayer at a seaside town you might, nevertheless, notice it with alarm! In very few places do the waves approach the coast parallel with the shore, and if they are parallel at



45. A common scene on sea-shores where the waves come in at an angle. The star part is played by a pebble.

one end of a bay they cannot also be parallel at the other. Now, when the waves are not parallel with the shore they not only rake the stones up and down the beach, but they drag them along it as well. This is explained in Fig. 45, where the dotted line shows the path a single stone is likely to take when the waves approach at an angle.

You can easily picture what happens when *all* the stones are dragged along like this. The whole beach is steadily moved along the coast, and a seaside town

which needs it for boating and bathing has to take drastic steps if it is not to lose its beach altogether. It does this by building low wooden or metal walls, called 'groynes', across the beach at right-angles to the shore. This divides the beach up into sections, and the stones cannot travel along it farther than from one groyne to the next. The duties of a groyne are thus quite different from those of a breakwater, though they are sometimes miscalled breakwaters. A breakwater is a massive stone wall placed so as to protect the ships in a harbour from large waves.

Groynes do their work very efficiently, and you may have noticed how the stones get piled up against one side of each groyne and are dragged away from its other side. It is just as if the beach had been swept up by a huge broom and piled into a corner. See Fig. 46. The difference in beach-level at the two sides of a groyne may be several feet, and nothing can show

46. How groynes prevent a beach from travelling along the coast.

more clearly the immense amount of broom-work the sea sometimes does along a coast.

This movement of the stones along a shore is called 'longshore drifting', and it accounts for the strange pebbles—which could not have come from the local rocks—that you may sometimes pick up on the beach. The sweeping goes on underwater, too, beyond the reach of the groynes, but here, on the sea-bottom, the stones are simply pushed along by currents in the water.

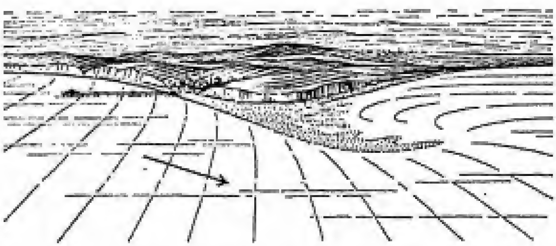
Where there are no groynes the sea often does sweep away an entire beach much faster than it can be replenished by stones from the cliffs. It goes on sweeping the stones along until the coast happens to curve round so as to face the currents. There can now be no more side-sweeping, so that at this point the stones accumulate in a vast 'shingle-bank'. This usually happens at the end of a wide bay, where the shore has been curving round to meet the sea for some miles, and here enough shingle may gather to build up new land.

One of the finest examples in the world is the great shingle-bank of Dungeness, in the English Channel. This projects six miles into the sea from the original coast-line, which formed a wide bay about three thousand years ago. During this time the sea has swept enough shingle along the south coast of England to build up a hundred square miles of new land. The total weight of all the pebbles moved must be something like ten thousand million tons, which means that about fifteen thousand million pebbles have been added to this shingle-bank every year!

If a bay does not curve quite enough to bring the stones to a complete standstill, the shingle-bank may

go on growing out to sea for many miles as a long, narrow tongue of beach called a 'spit'. The tip of the spit, being too far from the firm land to be safely supported, generally gets bent round into the form of a horn by the force of the waves. This is illustrated in Fig. 47.

The sea on the sheltered side of this horn is now protected from the waves and remains comparatively calm. Mud and sand may settle in it, especially if a



47. A scene showing the formation of a spit and the beginnings of a salt-marsh. The arrow shows the direction of the waves.

river happens to come down at that point, and a 'salt-marsh' may result. Here, sea-plants like samphire and statice ('sea-lavender') grow, and the area may be known locally as the 'saltings'. (Of course, salt-marshes are found in many other places as well—for example, around river deltas.)

The stones travelling along a coast may come suddenly to the mouth of a river, and then they will probably form a spit right across it, forcing the river to take a sharp turn. It now flows parallel with the coast until it finds an opportunity to break through the spit. A classical example is the river Alde, in Suffolk, England. It flows to within fifty yards of the

sea near the town of Aldeburgh, but is then cut off by a spit running parallel with the coast for eleven miles, when at last the river breaks through. Old maps show that this spit has grown at the rate of six miles in four hundred years.

Spits are built up by the sweeping action of the waves, but on many coasts the sea does the very reverse of building. In places where there is no beach, or from which the beach is being rapidly removed, the waves attack the land and destroy it by the power of their own weight. When you see large, breaking waves come rolling in, one after the other, you cannot fail to be impressed by the enormous quantity of water that falls on the shore or is hurled against the cliff. A wave 200 yards long and high enough to put you out of your depth as it passes may weigh 800 tons. This is the sea acting as a battering-ram.

The league-long roller thundering on the reef *

grinds up the stones by smashing them against one another, and if it strikes the cliff it may shake down great masses of rock. It can batter a stout ship to splinters in a few hours. During a big storm the waves may beat against the cliff with a force of three tons on each square foot, which is as if the side of your house were struck suddenly by a giant sledge-hammer weighing more than a thousand tons!

No house could withstand such an attack, but the cliff receives such blows every few seconds for as long as the storm rages—perhaps for several hours. If the sea enters a cave, it puts such tremendous pressure on the walls that it may force them apart or burst a hole in the roof. More often it shakes loose blocks from

* Tennyson, *Enoch Arden*.

the roof until a hole appears, and this is called a 'blow-hole', or 'gloup'. Every large wave may now force a fountain of spray up through the gloup, to a great height in the air.

Where there is a narrow beach the waves will pick up the stones and hurl them against the cliffs as if bombarding them with shrapnel. Pieces are chipped off incessantly and as they fall they are swiftly raked out of the way to expose more of the rock to attack. Waves smashing against a projecting rock may be flung up to a hundred feet or more by the force of the impact, and shower the cliff-top with pebbles. The heavier stones do not rise so high, so that most of the chipping work is done at the foot of the cliff, and this is why most cliffs have a sort of 'nick' cut in them all along their bases.

At any weak place, such as where the rocks are cracked or jointed, a cave may be hollowed out. On coasts where the sea can reach the foot of the cliffs at high tide this work goes on slowly all the time, whether there is a storm or not, for even a little wave can do *some* work. It just takes longer, and it naturally takes longer also to wear away hard rock than soft. But—

No rock so hard, but that a little wave
*May beat admission in a thousand years,**

and wherever the sea meets the cliffs it gradually destroys them.

The nick that it cuts into the base removes the support for the rocks above. They begin to overhang and presently fall by their own weight. Thus, the sea adds to its other methods of destruction that of a man

* Tennyson, *The Princess*, III, 7.

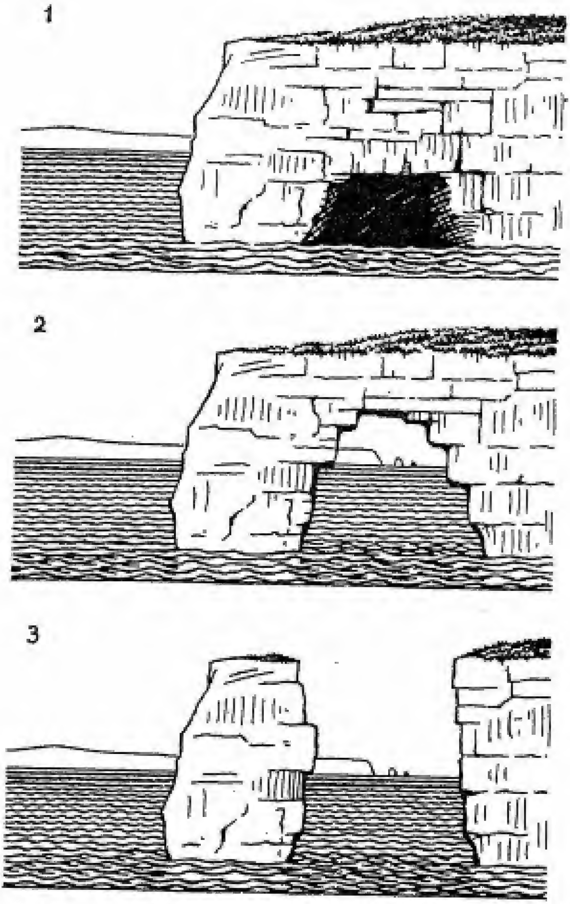
felling a tree. The lumberman cuts a deep notch into the base of the trunk with his axe until the tree at last falls over, and when the sea cuts into the base of a cliff, using myriads of small stone axes with tireless patience, it achieves the same result in the end.

The bays and headlands round the coast often indicate where the rocks change from hard to soft. The sea removes the soft rocks most rapidly and appears to take great bites out of the land, but when it has done so, the hard rocks of the headlands are all the more exposed to the waves. They may now be attacked on both sides and this can produce many picturesque details in the scenery.

For example, a cave started on one side of a headland may get deep enough to meet the back of a cave on the other side, making a tunnel through it. The roof of the tunnel forms an arch, but if this falls in it leaves a column of the cliff standing by itself in the sea. Such a column is called a 'stack'. These events are illustrated in Fig. 48.

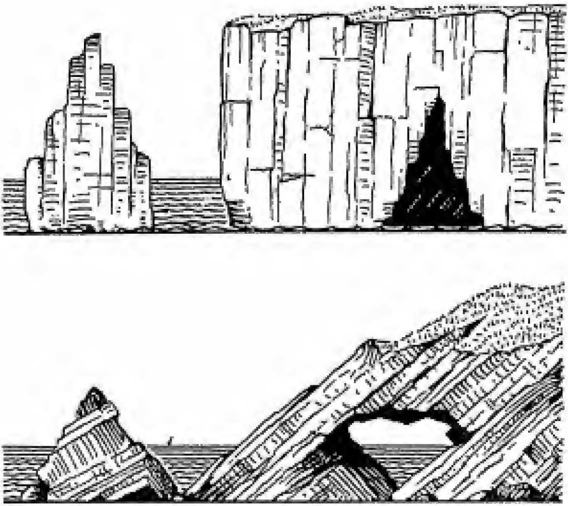
The particular forms of caves, arches and stacks depend on the way in which the rock strata lie. If they are horizontal we get square-mouthed caves and flat arches (as in Fig. 48), but if they are tilted at an angle the openings are likely to be pointed. If they are vertical we get upright columns and pyramids. Thus, the cliffs get carved into a sort of architecture, now showing one style and now another, so that the sea also performs the office of 'stage architect', though it does its building in the rather odd way of pulling things down instead of putting them up!

Two of these forms are shown in Fig. 49, and in Fig. 53 you may see a stack in which the strata slope downwards away from the sea instead of towards it.



48. This shows how the sea may change a cave into an arch, and then widen the arch so that the top falls in, leaving a 'stack' standing away from the shore.

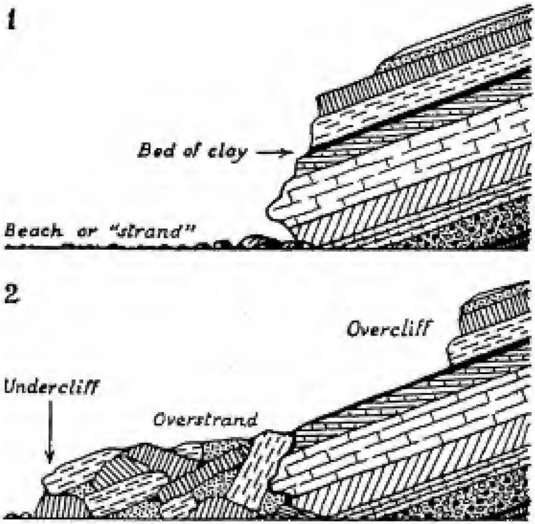
When they slope towards the sea the cliffs may be very unsafe. For example, if there is a sloping joint or a layer of clay half-way up the cliff, the rain soaking through may make it dangerously slippery. One day, when the cliff has been struck by a very heavy sea, all



49. Cliff architecture: stacks and caves or arches when the strata are vertical and inclined. The shapes produced by horizontal strata are shown in Fig. 48.

the rocks above the layer of clay may come sliding down and pile up on the beach. See Fig. 50.

This is called a 'landslide', or 'landslip', and provides some more familiar landscape forms. The rocks that have fallen make a sort of shelf along the beach and this is often called an 'overstrand'. Its steep outer edge now becomes the 'undercliff' and the part of the cliff still remaining above it is the 'overcliff'.



50. A dramatic act in two scenes. In Scene 1 a sloping bed of clay becomes slippery by rain-water soaking through from above. In Scene 2 the top of the cliff slides down the slope and crashes on to the beach below in a 'landslip'.

In such ways does the sea carve and build and shape the coastal scenery, and it performs these duties steadily while the crust of the earth itself remains at a constant level. If the land begins to rise or sink while the sea is at work, a whole lot of new forms may appear, and these we shall look at in the next chapter.

6

New Lands for Old

The crust of the earth, whose slow movements cause the folding of the rocks and the raising of plateaux, and the work of the sea together produce landscape effects on the grandest possible scale. The motions of the crust were outlined in Chapter 1, and it acts sometimes like a bulldozer, pushing against the rock-strata so as to buckle them up, but sometimes like a lift or hoist, raising the strata without otherwise disturbing them. The sea joins in these activities, both as a plane to smooth off the tops of the folds, and as a hydraulic press to squeeze the layers of sediment into hard rocks which may later be raised and exposed to the weather.

Let us first see what happens to the coast when the land rises. The sea naturally runs off its shores; it is as if the tide went a long way out—to stay. The waves are no longer able to reach the cliffs, even in a storm, so that the work of cliff-destruction ceases. The old cliffs may now get slowly weathered into nice, round hills, all covered with grass.

Meanwhile, the old level that formed the beach may have become half a mile (or even many miles) wide. If it happens to be of clean, deep sand it forms a sort of desert along the shore. It is true that rain may often fall on it, but the rain soaks straight through the

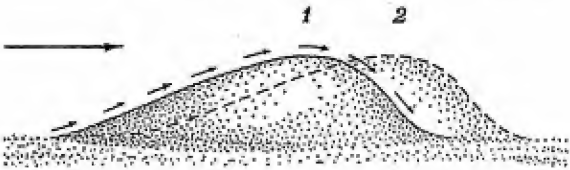
sand and nothing has a chance to grow. Every time the wind blows it picks up the loose sand-grains and whirls them about, and if a weed has dared to appear anywhere it is promptly buried. Even a light breeze will trundle the grains along the surface—until they get stopped by a hillock or a small boulder. At such places they will accumulate and gradually form a sand-hill, or 'dune'.

Dunes are particularly interesting as landscape features, for they are the only kind of hill that walks about! Dunes never stay for long in the place where they were formed, but as soon as they are large enough they move camp whenever the wind gets up. What happens is that the wind blows the sand-grains up one side of the dune, and they roll down the other side. In this way, the sand is being continually transferred from one side of the dune to the other, and so the whole mass of sand travels along without losing the form of a hill.

You can illustrate this by an experiment. Put six pebbles in a row, touching each other, on the table. Now lift up the pebble at the left end of the row and carry it over an imaginary hill to the right end. Then take the new left-hand pebble and repeat the flight over the hill, and so on. Keep moving the pebbles from left to right in this way, one at a time, and the row will gradually travel across the table without ever losing its shape as a row of pebbles. That sand-dunes travel in the same way is shown in Fig. 51, where the big arrow stands for the wind and the little arrows for the movement of the sand-grains.

In countries where the wind blows steadily in from the sea for the greater part of the year, the dunes may travel inland and gradually bury fields, farms, villages

and even whole forests with sand. Many thousands of square miles of good land have been overwhelmed and ruined in this way in Scotland, Holland, Germany, France and many other countries. The only way to check such an invasion is to plant special kinds of grass, such as marram-grass, which will grow quickly in sand and bind the grains together with their roots. This sort of grass not only grows faster than the sand

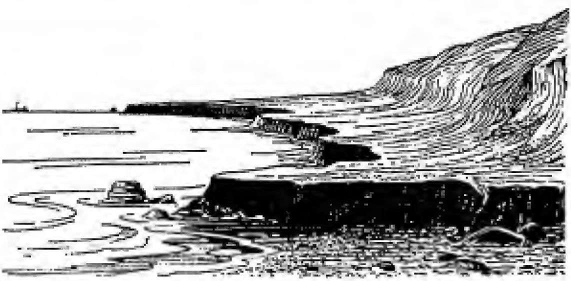


51. How a sand-dune travels along. As the sand-grains get blown over and over by the wind, the dune moves from position 1 to position 2.

can bury it, but it spreads rapidly and its tufts shelter the sand behind them from the wind.

Now let us suppose that the old shore-land that has become so wide is not a sandy one, but consists of pebbles between which dust and dirt have collected. Very likely there is mud underneath as well, and the rain soon washes the salt out. Here, grass and other plants begin to take root naturally, and their dead leaves mingle with the dirt to make a soil. This land may become rich enough to support farms and even villages, and trees may grow on it. Presently, there is nothing to show that this wide strip of land was once a sea-beach, except the line of hills showing where the old cliffs used to run, though you may see it referred to in a guide-book as a 'raised beach'. Another name for such a wide strip is a 'coastal plain'.

If the land now ceases to rise any farther, the sea will have a chance to cut a new cliff into its edge along the new shore. It has probably done this, anyway, but it is, of course, only a low cliff. If the land rose altogether about twenty feet, then the new cliffs cannot be more than twenty feet high, but they give a novel appearance to the scenery. They seem to put the coastal plain on to a sort of platform, very much like a wide river-terrace, and the two formations do really have the same cause. The name we gave to it in Chapter 2 was 'rejuvenation'. The land rose, so the river cut deeper and left a terrace, and here the sea cuts deeper and leaves a sea-terrace—which is all a raised beach really is. See Fig. 52.



52. Sea-shore scene, showing a raised beach with the old lines of cliffs behind it.

When a river comes down to the sea on a coast that is rising, something else again may happen. Water runs downhill or not at all, and as the coast rises the lower parts of the river get less and less steep until the water is brought almost to a standstill. It eventually cuts a deeper channel for itself, but at first it simply

drops its load and goes on strike. It quietly overflows on to the surrounding land and makes a marsh which may be difficult and expensive to drain.

On coasts where the rocks are hard there may be other signs that the land has risen. When the sea makes a beach and rakes the stones up and down, it grinds a level surface like a table on the rock underneath. If the land then rises a little way the old beach may soon get swept off the table and leave the bare rock exposed. It is called a 'wave-cut platform' and one is illustrated in Fig. 53. You can see clearly how the sea has planed off the rocks, almost as a carpenter planes a board. In Norway, there are wave-cut platforms of hard igneous rocks which are thirty-two miles wide in some places.

The platform shown in Fig. 53 is cut in sedimentary rocks, and you will notice that the strata are highly tilted. This is very clear in the stack like a pyramid in the background, but when the sea is doing its planing it takes no notice of how the strata are arranged. It works at only one level—the level it can reach between high and low tides—and it cuts and grinds away regardless of obstacles. Only the hardest blocks of rock can hold out against it.

All these examples have one thing in common. The land that rises slowly out of the sea is the flat sea-bed, so that the new coast-line is free from deep inlets and the water is shallow for a long distance out to sea. As it comes up, an off-shore bar (see page 96) may now poke above the surface and form a long 'barrier beach', parallel with the shore and enclosing a 'lagoon'. One of the best examples of this is found in North Carolina, where there is a barrier beach—broken by small gaps here and there—about two

hundred and fifty miles long. It encloses many lagoons, and on the flat coast behind there are more than two thousand square miles of swamps and marshes, where drainage has been checked because the land is now practically level.

This great barrier beach has probably been added to by longshore drifting, and you can find it easily in the

53. A wave-cut platform in Wales, with all its beach-material washed away by the sea.

map of the United States in your atlas, where a sharp angle half-way along it is named Cape Hatteras. The famous beaches of Daytona, Palm Beach and Miami are similar off-shore bars in Florida.

Now let us see what happens on the coast if the land stops rising and then begins to sink. Before it begins to sink it may remain steady for a time, and then the sea gets on with the work described in the previous chapter. It attacks the cliffs and makes beaches. But it may already have occurred to you that it cannot go

on doing this for ever. After it has knocked down a lot of cliff its beach may become so big and wide that it can no longer reach the cliffs. It can now spend its energy only in beating the shingle into sand.

The attack on the cliffs can continue only if the beach is somehow removed as fast as it is formed, and we have already described how this can happen by longshore drifting. But the beach can also be removed in another way. If the land on which it rests begins to sink it disappears beneath the waves, and this also leaves the cliffs unprotected. The sea goes on chipping away at their bases, grinding a wider and wider platform as it advances. It may, indeed, slice the top off an entire island so that not a rock remains to show above the waves.

It has done this times without number in the past, sometimes levelling off whole countries and the greater part of some continents. So long as the land goes on sinking there is nothing to stop it. When, at a much later date, the land rises again, these old planed-off surfaces come up as 'plains of marine erosion' (or 'denudation'—it means the same). They are like the wave-cut platform already described, only they are much too big to be called 'platforms'. They are rather vast 'stages'—stages which, if they rise to form plateaux high enough to be carved up into mountains, will presently exhibit entirely new sets of scenery.

Like the wave-cut platform, a plain of marine erosion has a level surface regardless of the arrangements of its strata, so that the kind of plateau illustrated in Fig. 5 (page 20) is not the only possible one. There, the plateau had a flat top because the strata were perfectly level. In this other kind the strata may

be folded and crumpled to an unbelievable degree, but the top will be flat because it has been planed off smoothly by the sea. The sea must have destroyed a lot of rock in doing this work, and the debris will undoubtedly have been deposited in horizontal layers on top of the worn-down surface, but the new plateau would be just as flat without them.

An old plain of marine erosion of this kind—scarcely high enough now to be called a plateau—is

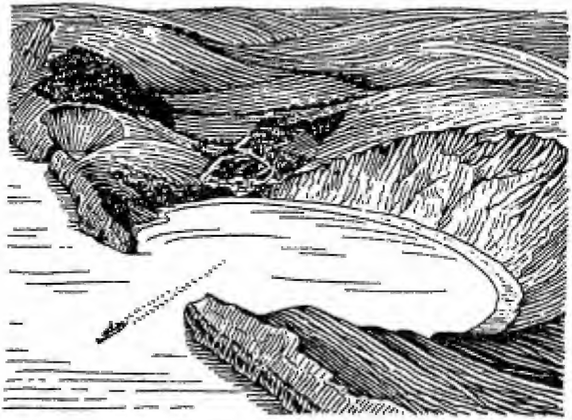
54. The level tops of these cliffs on the north coast of Cornwall, England, were planed off by the sea when the land was 430 feet lower.

shown in Fig. 54. Any horizontal layers that may once have rested on top of it have long since disappeared, and the land is once more sinking. The sea is attacking it again at the foot of the cliffs, cutting deep inlets where its folds and faults expose softer rocks.

The folds and faults may in this way have much to do with the details of coastal scenery, though unless they can be clearly seen in the cliffs (as they often can) it takes an expert to discover them. When we find

alternate headlands and deep bays it is usually because the strata are steeply inclined, like books on a shelf but not nearly as tidily, so that hard and soft rocks alternate along the shore.

When the folds in the strata run parallel with the shore we get a different kind of coast. At some time it will happen that all the rocks facing the sea belong to a very hard bed which stands up more or less like a wall, and then there will be very few bays or inlets. But eventually the sea will make a breach in the wall, perhaps by taking advantage of a fault, or by widening the mouth of some little stream that has cut itself a gorge. Once through the wall, the sea will rapidly get to work on the softer rocks behind and scour out a nearly circular bay of the kind shown in Fig. 55.



55. An air-view of Lulworth Cove, Dorset, showing how the sea has broken through a wall of hard rock. The smaller circular cove on the left is Stair Hole, the inside of which is shown in Fig. 2.

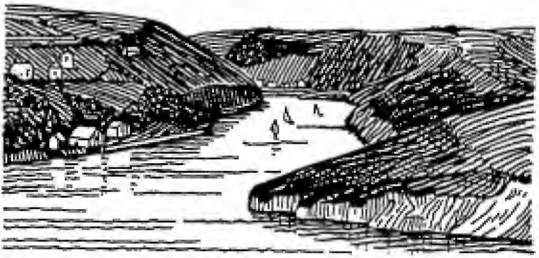
These are two well-marked kinds of coastline, but when the rocks are arranged in other ways, or when they consist of shapeless masses of igneous rocks, like granite, the details of the shoreline may be too complex to sort out. We can only make a note of the forms we can easily recognize, and we may feel very pleased with ourselves when we come across really good examples of typical formations. It is then a good idea to make a record by sketching or photographing them.

It is easy, however, to recognize two more general types of coast, which have been caused directly by the sinking of the land. These result from the simple flooding of the land by the sea. Naturally, as the land sinks the sea flows up the mouths of the rivers and floods their valleys. This makes even little rivers seem to have mouths that are much too big for them, but that they are not genuine mouths is shown by the fact that they contain salt water instead of fresh. They are called 'estuaries', and they have high and low tides which may be even more marked than those on the open sea-board. When the tide comes in, the river may be forced to flow backwards for some miles until the tide turns again.

The land which becomes flooded at the river-mouth is the old river-plain, and at first it becomes a salt-marsh. When it sinks entirely beneath the water the sea reaches right across to the walls of the old valley. The banks of the estuary are now at the foot of the hills, but though they are steep the water remains shallow and its bottom flat, except for a deep channel in the middle where the river used to flow. In the shallows mud may settle and form banks and shoals that are liable to move about, like sand-dunes,

when the tide flows over them. Such shifting mud-banks cannot be charted and are dangerous to shipping but, like the dunes, they can be controlled by sowing special grasses, such as spartina-grass (which will grow with its roots under salt water).

Fig. 56 shows a small but typical drowned river-valley. As you sail up it the water gets steadily shallower and the channel narrows as the walls of the valley close in. This type of estuary is called a 'ria'



56. The drowned valley of the river Solva, in Wales. The old slopes of the V-shaped valley can be seen above the new sea-cliffs.

(Spanish for river-mouth) to distinguish it from another kind called a 'fjord', found in northern lands, and in South Island, New Zealand.

Fjord (or fiord) is the Norse name for a drowned glacier-valley and it differs from a ria in several ways. To start with, a U-shaped glacier-valley has much steeper walls, so that the inlet is often bounded by high cliffs instead of hill-slopes, and there is no plain to provide a flat shallow bottom. The remains of the old terminal moraine may make the water shallower just at the entrance, so that as you sail up a fjord the water may get steadily deeper for some distance.

Often, too, the inlet gets wider as you go up it, instead of narrower.

But no matter whether the drowned valleys are rias or fjords, the coastline where the land has sunk is likely to contain many such inlets and is said to be deeply 'indented'. It may contain many fine harbours. This is exactly the opposite of what we found on a coast that has been rising, for there the land has had all its irregularities smoothed away by the sea or covered up with shingle and sand. Rising coasts are thus generally smooth and flat, but sinking coasts hilly and full of deep inlets.

We are now going to follow the sinking coast right down under the water. As it sinks the sea planes it off in the way we have described, so that although the shore-line may consist of hills and steep cliffs, the part under the water has already been levelled and covered with the shingle raked down from the beaches. Farther out the bottom is covered with sand, and beyond that with mud. Added to these deposits there may be enormous quantities of similar materials brought down by rivers, and it all settles down quietly on the sea-floor.

We now have a picture of a bed being made. The bed is the bed of the sea, and the blankets and sheets are the layers of pebbles, sand and mud that settle on it. At first the bed-clothes may not be very wide. Unless the rivers are really large their load, and the beach material, will all be dropped within a few miles of the shore, though underwater currents may sweep them farther out. But as the sea goes on encroaching on the land the layers of sediment grow wider and wider. If a whole continent is submerged they may finally cover a million square miles or more.

The sea-bed may still go on sinking and the sediments accumulating on it become very thick. Eventually, the original sea-bed may have subsided to a depth of some miles, yet the water may not be nearly as deep as this because the sediments on the bottom may themselves be more than a mile thick. You see, all the time the sea-floor is sinking it is getting partly filled up again, and this can go on for a very long time.

The bottom layers naturally get very firmly compressed by the weight of all the sediments above them. A square mile of sediments one mile thick weighs about 10,000 million tons, and this enormous pressure is sufficient to make the grains stick together and become solid rock. The upper layers of the sediments are squeezed by the weight of the ocean, for even where it is only 600 feet deep a square mile of sea weighs about 500 million tons. No wonder, then, that the layers of pebbles, sand and mud at the bottom of the ocean

> *. . . suffer a sea-change*
> *Into something rich and strange,**

though it is more often strange than rich!

The sediments are made into rock by pressure, just as artificial coal-bricks are made from coal-dust in a hydraulic press, but the sea works another remarkable change as well. It partly dissolves the grains so that they weld on to each other, and this converts them into very hard rock indeed. Something similar happens when sugar or salt gets damp and sets into hard lumps, only the grains of sand and mud are much

* Shakespeare, *The Tempest*, I, 2.

less soluble than salt or sugar and take a much longer time, besides being under great pressure.

In this way the sand-grains become hard sandstone and the mud clay or shale. The pebbles will not stick together directly for they touch each other at so few points, but where other sediments have settled down between them they may all get cemented together. The result is a sort of natural concrete; it looks rather like a plum-pudding, with stones for plums, and it is commonly known as 'pudding-stone'.

Along some shores, where the rocks are hard and there happen to be no rivers, there may be very little sediment to accumulate. The water is clear and suitable for the growth of corals and sea-lilies, and ordinary sea-shells are found in great numbers. All these shells are made out of carbonate of lime, extracted from the sea-water by the living creatures which inhabit them. When they die their dead shells gradually carpet the sea-floor so that we presently get a bed of carbonate of lime instead of sand or mud.

In deeper water there are minute creatures whose tiny shells float near the surface while they are alive, but sink to the bottom of the sea when they die. These make another carpet of carbonate of lime, farther out, and it is so fine that it is called an 'ooze'. Oozes of one sort or another* cover the floors of all the oceans where they are out of reach of material supplied by the land. Now, wherever the sediment is of carbonate of lime, from whatever source, it suffers the same kind of sea-change as the sand and

* As well as the limy oozes there are flinty ones composed of another kind of microscopic shell, and a 'red ooze' which consists of dust blown out to sea from the smoke of volcanoes.

mud, only the rock it forms is called limestone.

Of course, shells are found on sandy and muddy bottoms as well as in clear water, but where there is much sand or mud the amount of lime contributed by the shells is negligible. Here and there one may become embedded in the rock that is formed, like the pebbles in pudding-stone, and later we may find it in the rock as a 'fossil'. Occasionally there may be enough shells to make the sandstone or clay 'limy', or even to provide a sheet of limestone between two blankets of clay or sand. But very pure limestones, like chalk, form only in seas that are free from sand and mud.

What happens next? Sooner or later the sea-bed, with its layers of newly-manufactured rocks, will rise again. Very seldom does it come up like a lift. It nearly always rises because it has been squeezed between two slowly-moving blocks of the earth's crust, as we illustrated in Fig. 1 (page 17). The beautifully level beds of new rock get bent and folded and buckled up, and some may now suffer further changes. For example, the clay may get changed to slate through being squeezed too hard, and the limestones may change to marble if they get heated with steam—which can easily happen at great depths or near a volcano.

Eventually, the new rocks will rise high above sea-level and become new land, and the stories told in this book will start all over again. But notice just one thing more. This new land, with its brand new rocks, is really made out of the smashed-up fragments of the old. If Aladdin's wicked uncle had cried, 'New *lands* for old!' instead of bothering about *lamps*, he would have expressed it very neatly!

7

Colour, Words and Music

THE framework of the scenery has now been put up and it remains but to paint and decorate it and provide for the sound effects. If you imagine that the world of rocks and mountains remains silent, except to echo the cries of living creatures, you are going to be surprised—though, to be sure, we have already mentioned the babbling of brooks, the moan of the sea and the growl of the geyser.

First, the painting. The commonest pigment used by nature is undoubtedly iron oxide, or rust. It appears everywhere, in various forms, and stains the rocks in all shades of red, yellow and brown. The blood-red colour of jasper, of which you may pick up pebbles on many beaches, is produced entirely by iron oxide, and so is the red of bricks and tiles—and all the other things made of clay (flower-pots, for instance).

The true natural colour of most clays is dark grey, blue, green or black, though you hardly ever see these colours (except in a freshly-dug pit) because they change when the clay is exposed to the air. The dark colours are caused by carbon and other impurities, and by a black oxide of iron, but when the clay is dug up they all disappear except the oxide of iron, which

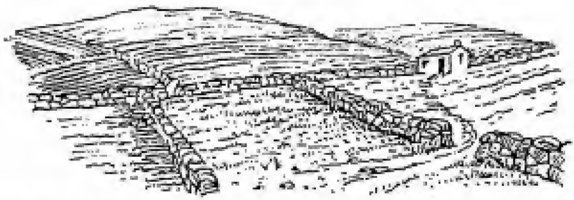
turns to yellow or brown rust. It is only when the clay is roasted in kilns, as in making bricks, that it becomes bright red, and even this does not always happen. If there is lime in the clay it will bleach out the colour and give white or grey bricks, and if the fire takes oxygen out of the clay the bricks may turn black or purple.

You may wonder why we should talk about bricks, which are manufactured articles and not part of the natural landscape. Well, most houses are built of bricks and we can nearly always learn something about the rocks of a landscape from the older buildings on it. Before there were railways and motor-lorries to carry heavy loads about, people used to build their houses and churches of the most handy natural materials they could find. So if you see an old town or village in which most of the houses are of brick you can be fairly sure that you are in clay country—or not very far from it.

Among the mountains and on the moors the colours of the older buildings may be quite different. Here, the only handy building material (except possibly wood) is the rock of which the mountains are made, and though it may be a red sandstone it is never the bright red of a brick. More often it is grey or white and the cottages are all of grey stone. Even the fields may be divided by grey stone walls, because it is difficult to grow hedges on rocky mountains. These cottages and old walls we may regard as natural decorations to the scenery, for their colour belongs to their districts just as surely as the rocks of which they are built. See Fig. 57.

In regions where the hills are made of chalk, or where chalk is to be found at no great distance, many

of the buildings will be of flint. All flint comes originally from the chalk, in which it occurs as black nodules with a white crust, and walls made of flint have a speckled, pepper-and-salt appearance. But the worn flint pebbles found in brown gravel are not suitable for building, so these will not show up except in gravel roads or drives. Old gravel roads are likely to have got their stones from a quarry in a river-terrace, though near the coast they may come from a beach.



57. A scene in bleak, moorland country where the fields are divided by stone walls. Compare this with the hedgerows in Fig. 58.

In slate districts the cottages may be built of great lumps of dark grey rock, but this is often white-washed so that here we must be cautious. Blue, green and purple slates appear everywhere on roofs, and these also must be treated with caution because they have been transported for roofing all over Britain for at least three hundred years. The tell-tale roofs are those that are *not* made of slate, but of thin slabs of local limestone, which is generally dark brown.

Other limestones, too massive to split into roofing tiles, give blue-grey and creamy building-stones, as well as white ones. Shales are not much used in build-

ing because they are seldom hard enough, but tough slabs rather like dark brown or black tiles sometimes appear in walls. They are of all sorts of sizes and thicknesses. In places where the rocks are igneous we may find building done in glittering grey or pink granite. Aberdeen, in Scotland, is sometimes called the 'granite city' because most of its buildings are made of stones cut from the local granite quarries.

These are rock-colours that may show up on landscapes which are otherwise covered with grass and trees, but we should also look for exposures of the bare rock in the quarries and in natural cliffs. The same colours should appear here, but there may also be many other coloured rocks that are not suitable for building. We may see soft blue shales, pink and yellow limestones, golden or green sandstones that crumble at a touch, or soft white chalk too dazzling to look at in the sun.

Where there are neither buildings nor exposed cliffs there may be ploughed fields. These, too, can give us a hint of the underlying rocks by their colour. The rich red soils of the west of England, for example, tell us when we are on the New Red Sandstone, and the white fields of the southern and eastern counties are found only on the chalk. Clay soils may be yellow or brown, and rich mixed soils found in river-valleys (though there may be no river in sight) are black with decayed plant-remains. In sandstone or granite districts the soils are often ashy-grey, or speckled black and white, but these are often easier to judge by the plants that grow on them.

The plants, indeed, may tell you a lot about the rocks from which they draw their food. On heaths, for example, where there is little else but bracken,

heather and occasional pine-trees, the soil is likely to rest on pure sandstone, or sandy gravel, or on an igneous rock like granite, for these plants refuse to grow on limestone and are not fond of clay. Gorse, broom, foxglove, sorrel and sweet chestnut prefer sandstone to limestone, too, but will also grow on clayey gravel. Rhododendrons and azaleas object so strongly to limestone that in some cultivated areas it is possible to make a map showing where limestone

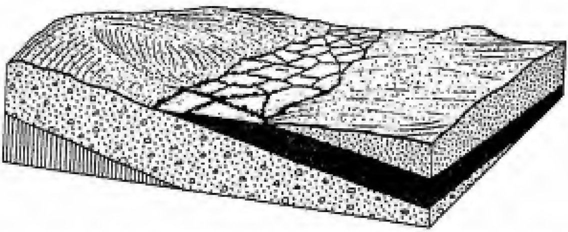
58. A 'cap' of beeches growing in a patch of clay on top of a chalk hill.

rocks change to sandstone or clay by simply marking on it the gardens and shrubberies where these plants grow.

If you do see such plants in limestone districts you can be quite sure that at those places there are small patches of clay, sand or gravel on top of the limestone. The example in Fig. 58 shows a 'cap' of beeches growing in 'clay-with-flints' on the top of a chalk hill. Many plants, however, require lime before they will grow at all. They include the beautiful blue scabious, the bee orchis, the fly orchis, viper's bugloss, wild cherry, cat's valerian, dogwood and deadly nightshade. Lime is also necessary for most farm

crops and has to be added artificially if there is not enough natural lime present. The common rest-harrow is an interesting plant, for though it is happiest on limestone, where it grows without thorns, it will also grow on clay, when it produces long sharp spines.

A very good example of the difference between sandy heath and limestone farmlands is shown in Fig. 59. Here, a bed of limestone is sandwiched



59. A block of country in west Surrey, England, where a sloping bed of limestone (black) is sandwiched between two beds of sandstone on which little will grow. Note the strip of rich fields where the limestone comes to the surface. The rest of the area is barren heathland.

between two thick beds of sandstone, and the strata are tilted so that on the surface a narrow strip of limestone crosses a wide area of sandy country. The sandy country is barren and useless, but the limestone supports a 'corridor' of rich farmland, the boundaries of which are marked by a quite sudden change in the vegetation. From a high aeroplane the country appears brown with a clean, green stripe across it—for all the world as if the landscape had been painted in strong, contrasting colours with a bold brush.

Clay soils are often found in river-valleys or over thick beds of shale or clay, and if they are not *too* stiff

they grow the best roses, potatoes, root-crops, wheat, oaks and willows. Willows are especially useful guides, for they like so much water that they are seldom found far from a stream and often grow along the banks of a river. If, from some vantage point, you can recognize a line of willows in the distance by their grey-green foliage, you can feel quite sure that they mark the course of a river even though you cannot see it.

The smaller clay plants, such as rushes and mare's-tails, are not so useful as clues to the underlying rock, though they always mark wet ground. They will grow in any mountain bog where the water cannot drain away, and though such bogs contain plenty of muddy clay the underlying rock may be granite. However, they have another use in such regions—they show you where it is unsafe to walk, for some mountain bogs are dangerously deep.

You would be surprised at the use surveyors sometimes make of wild plants as clues to the rocks hidden beneath them. They pay less attention to cultivated plants because farmers and gardeners 'doctor' the soil with lime and fertilizers, though even farmlands change in general character from district to district. Sometimes grasses are the most useful tell-tale plants, and even the health of the animals grazing in the fields may betray the kind of rocks on which their pastures grow!

It is fortunate that most of the rocks of the landscape are hidden by vegetation, for we should soon become weary of seeing nothing but harsh rock in every direction. We have (at the very beginning of this book) compared the turf which clothes the hills with a tight-fitting green vest, but it wears thin in places

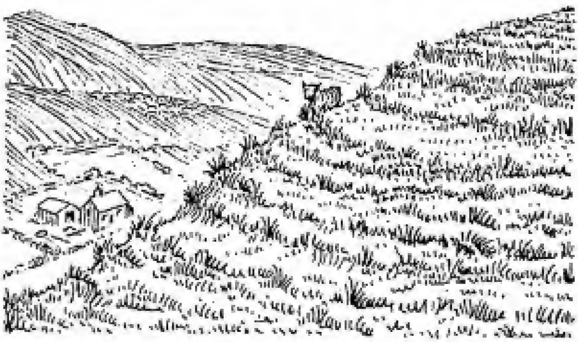
and the rocks poke through it like wrists and elbows, serving in their turn to break the monotony of the green. But these knobs and knuckles of rock also provide the landscape with furniture, for they often make convenient chairs and tables and are sometimes entirely upholstered in moss-cushions of deep green velvet.

At the head of the mountain-pass the bare face of the rock towers over us and may indeed appear forbidding, but if you look closely you will see that it is a weather-beaten face, softened and rounded here and there by mosses and caressed by the tiny fingers of the lichens. These lowly plants also modify, in another way, the rocky walls of gorges and steep valleys, staining them with mottled greys and delicate yellows, and printing on them faint patterns of blue and green stars and scarlet elf-cups. Their little papery scales and silken threads provide our scenery with wall-hangings, so that Ruskin calls them 'the dark, eternal tapestries of the hills'.

But there is something else to notice about that green vest of the turf, which is knitted with grass-roots and clings so tightly to the soil. It is, as we have said, a tight-fitting garment, yet there are places where it is loose enough to get rucked up. This shows in the rows of narrow ledges or steps that sometimes appear along the sides of the hills. They are often called 'sheep-tracks', but though sheep and human beings may find it convenient to use them they really have nothing to do with animals. They are just rucks.

They are caused by the weight of the soil, which tends to slide down the hill by a process called 'soil-creep'. Soil is a loose mixture of stones and tiny

grains and it has difficulty in 'staying put' on steep slopes. Were it not for the roots of the grass that bind it, it would all wash off in a few heavy showers. As it is, it slips just as far as the grass-roots let it—generally no more than a few inches. A succession of slips may add up to a foot or two, but after that it will stay in place for some time, forming a flat step on the hillside along which we may walk. See Fig. 60.



60. 'Sheep-tracks' on the side of a hill, formed when the soil slips down until it is stopped at intervals by grass-roots.

In parts of America, Africa and some other countries, there are semi-desert regions where the occasional rains are very violent, the water pouring over the hills in sheets. It sometimes gets underneath the thin turf, which then slides right off the hillside, leaving a wide gash of bare soil in which the rain scours out deep gullies. This is called 'rain-gashing', and when it is widespread the whole country shows nothing but naked rock and piles of barren soil. Plants are given no chance to grow and so we find a dreary earth-desert, useless and almost impassable to

travellers. In America such regions are called 'bad-lands'.

Badlands may also be caused by cutting down too many forests on mountain-slopes, for trees protect the ground from 'soil-erosion' (as it is called) even better then turf. And where dust blown from a desert piles up in a rainy region too quickly for the plants to make a permanent cover, as it does in parts of China, for example, you again find badlands. Thus, rocks and soils which may be colourful and interesting as decorations to the scenery can form the most dreadful landscapes imaginable when they make up the whole of it.

It is true that some of the great deserts of the world present magnificent views to the traveller, but they are impressive chiefly because they are so vast. You must have seen pictures of the deserts of Arizona and Colorado, the great seas of sand in Arabia and the Sahara, or the stony deserts of the Kalahari and Patagonia, but you wonder more at their emptiness than at what they have to show. Here and there are displays of marvellous colours, or fantastic sculptures carved by blown sand, but everything is deadly still in the glare of a pitiless sun.

A pleasant landscape which never wearies the eye is always 'clothed'—that is to say, it is covered with a mantle of vegetation which not only hides the harshness of the rocks but is always varying its colours. In spring and summer there are orchards in blossom, banks of primroses, patches of violets, fields of yellow mustard or buttercups, hedges of wild rose or honeysuckle, woods carpeted with bluebells, wastes splashed with the scarlet of poppies, the pink of willowherb or the white heads of daisies, moorlands showing miles

of purple heather and golden gorse. In the autumn there are the reds and russets of the falling leaves, and even in winter there is a vast range of quiet tints brightened here and there with scarlet berries. These, and all the imaginable shades of green between yellow and blue, are what we chiefly see when we look at most landscapes.

But however the landscape is covered and decorated it is the rocks beneath which give it shape and form, just as your body gives shape and form to your clothes, and most of this book has been concerned with the 'body' of the landscape. Yet we have tried not to lose sight of its coverings and decorations and have, indeed, compared them with many things besides clothing. They have reminded us of hanging drapery, carpets, ornaments, sculpture, architecture, furniture—and even paint or enamel, and the very word 'scenery' has suggested the scenery on a stage. This last idea (which, you may remember, was also our first) must be very ancient indeed—much older than Shakespeare—for the word 'scenery' itself comes from the Greek word *skene*, which means a stage. The idea behind it is a raised platform for the presentation of a spectacle or a play, so that nearly all the classical authors have felt obliged to specify 'natural scenery' when they mean the landscape.

We may certainly regard the landscape as a kind of 'spectacle' to watch, for there is always something going on that is worth looking at. Nothing is ever quite still, and in this place or that the action may be very vigorous and rapid. We have already read of breaking waves, heaving rocks, meandering rivers, tumbling waterfalls, travelling sand-dunes, sliding glaciers,

spouting geysers and of the heavy, massive sea that makes its weight felt so effectively

*Where the broad ocean leans against the land.**

These natural activities never cease and so the show goes on—endlessly. If we cannot at once grasp the thread of the story it is only because it is being told so slowly. When we watch this 'play' we are usually looking at scenes which began to be enacted long before we were born, and will not reach their climax until many more generations have passed. We have to puzzle out what is happening and may amuse ourselves by guessing at the future as well as at the past.

We often see a rock that is partly weathered away, but we seldom actually see the weathering going on—though we may occasionally hear the clatter of a falling stone as it goes to join the scree. We see a river cutting a valley, yet it generally looks the same on Tuesday as it did on Monday. The 'actors' often seem to be struck motionless in postures, as if frozen suddenly in the middle of some tremendous movement. The spectacle is none the less dramatic for that, however, and the very slowness of it is partly why it is so impressive. The contrast between the apparent violence of nature and her endless patience, always getting her own way in the end, was put quaintly into verse by an unknown gentleman (or lady) in the year 1587, as follows:

The sturdy rock, for all his strength,
By raging seas, is rent in twaine;
The marble stone is pearst at length
With littel drops of drizzling raine.

* Goldsmith, *The Traveller.*

Some poets have tried to speed up the action of the play and they have certainly found a new way of viewing the longer scenes. The average age of a landscape is said to be about a million years, and during that time mountains are raised up and worn down again—first into hills and then to a plain that finally disappears beneath the sea. If we could record all this on a film and then run it through the projector very quickly, we should see the world as a sort of fairyland in which

> *The hills are shadows, and they flow*
> *From form to form, and nothing stands;*
> *They melt like mist, the solid lands,*
> *Like clouds they shape themselves and go.*

The poet who wrote this—Tennyson—also looks at the sea and pictures the land that has sunk beneath it. At the bottom of the ocean lies a country that was once covered with forests and inhabited by countless creatures, but all have now vanished from sight and become buried in the ooze. This is another act in the drama, and yet another may be seen when we look at a modern city set in a happy countryside and remember that this landscape, too, was once at the bottom of an older sea, in which it gathered the rocks of which its foundations are made. Tennyson gets both these acts into a single verse (two lines for each):

> *There rolls the deep where grew the tree.*
> *O earth, what changes hast thou seen!*
> *There where the long street roars hath been*
> *The stillness of the central sea.*

If the whole play could be run through as quickly as that, what an epic it would make!

Now, what about the sounds that accompany this tremendous spectacle? There is certainly music enough and to spare, and on some shores, for example, you may even hear 'singing' in the sands. Not *on* the sands, mind, but *in* them! In Britain there are singing sands in North Wales, Dorset and other places, and they are found in many other parts of the world. They are usually found in patches between the sand-dunes and the sea-margin, and when disturbed in any way they sing a shrill note that may become a kind of deep, musical roar.

It is an eerie sound, especially when produced by the wind blowing over the surface, and nobody has yet explained its cause. The size of the sand-grains probably has something to do with it, and they seem to be just smooth enough to shift over each other in a jerky sort of way. They will sing if you drag a stick across the surface and roar if you walk over them. You can put them in a bowl and take them home, when they will sing if struck with a wooden spoon.

Another coastal sound may be heard from the cliffs when waves force compressed air through a gloup (page 107). During rough weather it may blow a musical note like a deep horn, or whistle like a piccolo. More often it makes a howling or roaring noise, hard to distinguish from the sounds of the storm. But air is, perhaps, most musical and most often heard when it blows as a breeze through the topmost branches of trees, where it moans and sighs and hums by turns, or faintly rattles the dead leaves like fairy castanets.

The humming of the telegraph wires is not entirely 'natural' music, for the wires have to be provided,

yet it is certainly a landscape sound—as is the roar of city traffic. But these hardly enter into this book. There are other weather sounds, however, which should at least be mentioned, because the weather plays such a very important part in the shaping of the landscape. The weather's contributions to our natural 'orchestra' include the swishing and patter of the rain, the drumming of hail, and the loud, crackling, drum-rattle that ends in a clap of thunder.

The weather, too—if we include the sunshine—provides the landscape with many colours which here we can only name. There is the pure white mantle of the snow, the dark gloom of lowering storm-clouds, the 'gleam upon gloom' of the rainbow, the blue of the clear sky, and all the glories of sunrise and sunset—golden, copper, crimson, green, scarlet and purple. All these colours are produced by air, water-vapour and ice-crystals, playing on the sunshine in various ways according to the whims of the weather.

The weather-noises, like the weather-colours, come in bursts and spells, but, by contrast, the sound of falling or running water in a landscape may not pause, even for a single instant, for tens of thousands of years! The noise of a waterfall is often like the cheering of a distant crowd, as if the slow, up-stream march of the fall deserved endless applause. But waterfalls, as we saw in Chapter 2, are only episodes in the lives of rivers, which in the end talk them down with their quiet gossip. The little streams, indeed, are the actors with the longest lines of all to say, and it is not without reason that Tennyson's Brook declares:

I chatter, chatter, as I flow
To join the brimming river,

For men may come and men may go,
But I go on for ever.

Have you not noticed how the sound of mountain streams can sometimes be mistaken for subdued voices? It is often like the unending conversation of people talking quietly in the next room, only it is never tiresome! 'I murmur under moon and stars', says the Brook, but it is a tuneful murmur that may become pure music where there are echoes. In the woods, for example,

. . . where two runnels of a rivulet,
Between the close moss violet-inwoven,
*Have made their path of melody.**

Even in the stillness of a limestone cavern there may be 'chamber music' of many kinds. Here the sounds are bell-like. The tinkling of runnels racing over stones is magnified by echoes from the walls, and the drops falling from the roof make a clear, sonorous sound like the solemn tolling of a minute-bell. And

. . . . listen too,
How every pause is filled with under-notes,
*Clear, silver, icy, keen, awakening tones.**

As for the words of the play—they are hard to make out! The only clear, unmistakable word that we ever seem to hear in this play is—'Ping!' It is uttered on mountain-tops when a flake of rock, strained by sun and frost, springs suddenly off and goes clattering down to join the scree. It is true we have also heard the Geyser growl his warning, and the earthquake make

* Shelley, *Prometheus Unbound.*

a rumbling noise that is perhaps more like some monstrous form of indigestion, but these are surely 'noises off'!

People have most often fancied they heard voices in the sea, for the mighty sounds produced by large masses of water in incessant motion, thundering and roaring in a storm or, when the storm is over, rippling multitudinously on the swell as it crosses the bar, 'vocal with wash of under wave', are so rich in variety that almost anything can be imagined in them. The pealing of a great organ, the singing of choirs, the shouting of triumphant armies—all these sounds have been heard in the 'voiceful sea' (as Coleridge called it).

But though the landscape play is not recited in words, it is often clearer than any words could make it. A rock which falls from a cliff needs no words to tell you it has fallen. After all, words are but the names we give to things and actions; the things and actions come first and 'speak for themselves'. And if actions speak louder than words, as the old proverb says, they also tell no lies. And so there is no better way of grasping the story of the landscape than by patiently watching what is actually happening in it.

The babbling, prattling, roaring, tinkling, murmuring and all the other sound-effects are not without meaning, however, for they are a real part of the landscape, which would be very dull and incomplete without them. So when you next find yourself in the country admiring the scenery, do not forget to listen for noises and to look for colours, as well as studying the forms of mountains and valleys. The sounds of birds, animals and insects are something

else again, all worth the closest attention, for the landscape is indeed very much more than mere rocks and water. This is true even when we forget—for a moment—to see it as a place for people to live in.

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